*MINISTRY OF AGRICULTURE, FISHERIES AND FOOD*
*DEPARTMENT OF AGRICULTURE & FISHERIES FOR SCOTLAND*
*DEPARTMENT OF AGRICULTURE FOR NORTHERN IRELAND*

**TECHNICAL BULLETIN 33**

# Energy Allowances and Feeding Systems for Ruminants

LONDON: HER MAJESTY'S STATIONERY OFFICE
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# Energy Allowances and Feeding Systems for Ruminants

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# Foreword

The decision to adopt a metabolisable energy (ME) system in place of the starch equivalent (SE), a net energy system, as the official advisory method for allocating energy allowances for ruminants, was taken at a joint conference on 'Nutrient Standards for Ruminants' held in London on 12 April 1972. This conference was held to consider reports of three working parties set up following an earlier conference at which the teaching and advisory implications of the ARC Review, 'Nutrient Requirements of Farm Livestock No 2—Ruminants' were discussed. Each working party had been asked to deal with the advisory implications of the ARC recommendations, one of which was to adopt an ME system on the principles suggested in the ARC report. The Energy Requirements Working Party undertook the task of evaluating the proposed ME system and of comparing it with the SE system in its ability to predict animal performance more accurately. The conclusion was reached that the new system was the superior and its adoption was recommended in a modified form better suited to advisory purposes. An outline of a modified version of the system was included in the report.

At the joint conference, the Chairman, the late Sir Ronald Baskett, expressed the view, which was agreed unanimously, that any proposed changes in nutritional standards or systems should be introduced on a United Kingdom basis. Consequently when, as a result of the joint conference, an ME System Working Party was set up with the object of seeking the most effective way of introducing a practical ME system in the United Kingdom, representatives from ADAS, the Department of Agriculture for Northern Ireland and the Scottish Agricultural Colleges were invited to serve on it. The members from ADAS were Messrs G. Alderman and D. E. Morgan (Chairman and Secretary respectively) who provided continuity from the previous working party, and Mr. A. Harvard who had taken a special interest in requirements for sheep and in tables of feed composition. From Northern Ireland, Professor J. R. Todd was able to bring experience in the use of the system for beef production. Dr. R. A. Edwards representing the Scottish College interests was an invaluable member because of his close association with the derivation by the Edinburgh School of Agriculture of a simple additive Variable Net Energy System from the original ARC proposals for growing and fattening animals. The Working Party decided that the principles of this net energy system should be adopted for use with the modified ME System. With Mr. Harvard, Dr. Edwards also prepared the present proposals for allowances for sheep. I should like to acknowledge the contributions of all members of the Working Party and to pay a special tribute to the enthusiasm and determination of its Chairman, Mr. G. Alderman.

The main function of this Working Party has been the preparation of this Technical Bulletin describing the derivation and use of the modified ME system in detail. This is the first bulletin to provide guidelines for the practical implementation of the modified ME system in the United Kingdom. Obviously research on all aspects of this topic continues. The present system is flexible and may be easily adjusted, when necessary, to include new data emerging from research. Further amendments to the bulletin will probably be needed during the next few years. The adoption of a policy of periodic review and revision will also meet another request, made at the joint conference, for a continued close liaison and exchange of ideas and information between advisers and research workers. Energy can be a major limiting factor in production from ruminants in the United Kingdom. It is hoped that those who use this bulletin in advisory work will find it helpful in overcoming many practical production problems related to energy requirements.

H. C. GOUGH
Chief Science Adviser
Agricultural Development
and Advisory Service

*May 1975*

# Preface

This bulletin is intended to be used primarily by agricultural advisers and teachers in the field of animal production. It is the first in a series of publications which will be required for the practical implementation of energy systems for ruminants based on metabolisable energy. The arguments for this change and the derivation of the simplified metabolisable energy systems have already been discussed in the Proceedings of the Seventh Nutrition Conference for Feed Manufacturers (Nottingham University, 1973). The current text is therefore, in the main, devoid of scientific references to support statements made.

The basic principles used are essentially those outlined in Section 6 of the Agricultural Research Council's Technical Review No 2 *Ruminants*, 1965. Also included are variable net energy systems for cattle and sheep which are adaptations of the system published by Harkins, Edwards and McDonald in 1974, based on earlier work by MacHardy. This approach offers considerable advantages in ration formulation for growing cattle and sheep.

As a means of expressing the usually simple relationships from which the systems are assembled, simple linear equations are given, but all the basic calculations can be performed by using the tables in the text. The equations have either been derived from basic data or are a good fit to the data, and are intended for use where greater accuracy is desired or for use in mathematical modelling. Because of the modular nature of the systems, modification or extension of the individual relationships should be easy to incorporate as new research findings become available.

Since agreement was reached in 1972 that these systems should be put into use by the autumn of 1976, when agriculture is due to assume its metrication programme, metric (S.I.) units have been used throughout. Food analyses are given as g/kg dry matter in the text and in the tables of food composition. The latter have been calculated from details of digestible nutrients of food, listed in ADAS Advisory Paper No 11 *Nutrient Allowances and Composition of Feeding Stuffs for Ruminants*, by the use of coefficients suggested by the Oskar Kellner Institute workers at Rostock, GDR.

The authors are indebted to Mrs J. F. B. Altman, Rothamsted Experimental Station, for the computation of metabolisable energy values of foods, metrication and verification of these tables.

GA AH JRT
RAE DEM

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## Terminology and Symbols used

| | | |
|---|---|---|
| APL | represents | Animal Production Level |
| BF | ” | Butter Fat Content (g/kg) |
| DM | ” | Dry Matter Content (g/kg) |
| DMI | ” | Dry Matter Intake (kg/day) |
| $EV_c$ | ” | Energy Value of Concepta (MJ/kg) |
| $EV_g$ | ” | Energy Value of Gain (MJ/kg) |
| $EV_l$ | ” | Energy Value of Milk (MJ/kg) |
| $E_g$ | ” | Net Energy Required for Body Gain (MJ/day) |
| $E_l$ | ” | Net Energy Required for Milk Production (MJ/day) |
| $E_m$ | ” | Net Energy Required for Maintenance (MJ/day) |
| $E_p$ | ” | Net Energy Required for Production (MJ/day) |
| FM | ” | Fasting Metabolism (MJ/day) |
| $k_g$ | ” | Efficiency of Utilisation of ME for Body Gain |
| $k_l$ | ” | Efficiency of Utilisation of ME for Milk Production |
| $k_m$ | ” | Efficiency of Utilisation of ME for Maintenance |
| $k_p$ | ” | Efficiency of Utilisation of ME for Production |
| $k_{mp}$ | ” | Efficiency of Utilisation of ME for Maintenance and Production |
| LWG | ” | Liveweight Gain (kg/day) or (g/day) |
| ME | ” | Metabolisable Energy |
| MEF | ” | ME of Food (MJ/kg) |
| MER | ” | ME of Ration (MJ) |
| MEP | ” | ME Available for Production (MJ/day) |
| $M_g$ | ” | ME Required for Body Gain (MJ/day) |
| $M_l$ | ” | ME Required for Milk Production (MJ/day) |
| $M_m$ | ” | ME Required for Maintenance (MJ/day) |
| $M_p$ | ” | ME Required for Production (MJ/day) |
| M/D | ” | ME Concentration in Dry Matter (MJ/kg) |
| $NE_g$ | ” | Net Energy Value of a Food or Ration for Body Gain (MJ/kg) |
| $NE_l$ | ” | Net Energy Value of a Food or Ration for Maintenance and Lactation (MJ/kg) |
| $NE_m$ | ” | Net Energy Value of a Food or Ration for Maintenance (MJ/kg) |
| $NE_p$ | ” | Net Energy Value of a Food or Ration for Production (MJ/kg) |
| $NE_{mp}$ | ” | Net Energy Value of a Food or Ration for Maintenance and Production (MJ/kg) |
| SNF | ” | Solids-not-fat Content of Milk (g/kg) |
| W | ” | Liveweight (kg) |
| Y | ” | Milk Yield (kg/day) |

# SECTION I

## Principles

### Food Energy

At the present time the basic unit of energy used in nutrition is the thermochemical calorie (cal) based on the calorific value of benzoic acid as the reference standard. Usually the kilocalorie (kcal), equivalent to 1000 cal, or the megacalorie (Mcal), equivalent to 1,000,000 cal, are used in practice because the calorie is inconveniently small. The Royal Society has recommended that the calorie should be replaced by the SI unit for energy, the joule (J). The joule-equivalent of the thermochemical calorie is 4.184J. By analogy with current practice the units employed will be the kilojoule (kJ) or the megajoule (MJ).

When a food is burned completely in a bomb calorimeter, energy is released and can be measured as heat. This is termed the 'heat of combustion', or more commonly the 'gross energy' of the food, and represents its total content of energy. Instead of gross energy, the recommended term 'energy value' (EV) is used in this bulletin. The energy value of an individual food is the sum of the energy values of its constituents. Carbohydrate, the dominant fraction of most foods, has an energy value of about 17.5 MJ/kg of dry matter. Fats contain about two and a half times, and protein about one and a half times as much energy as carbohydrates while ash has no energy. As the protein and/or fat content of a food increases so does its energy value. In contrast, foods of high ash content have low energy values. Since carbohydrate is the dominant fraction in most foods, energy values are normally about 18 MJ/kg of dry matter.

Not all the energy value of a food is available to the animal. Part of it, that which is not digested, is voided in the faeces and its energy lost to the animal. The difference between the energy value of the food and that of the associated faeces is the 'digestible energy' (DE) of the food. This concept assumes that all the food energy which does not appear in the faeces is digested and absorbed by the animal and that all faecal energy originates in the food. This is not strictly correct and the figure should be referred to as the 'apparently digestible energy', as distinct from the 'truly digestible energy' which is a rarely used concept. The digestibility of energy varies within wide limits for different foods. Thus in barley straw it is about 0.45 while in cereals such as barley it is about 0.85.

A further loss of energy from the alimentary canal occurs in the form of combustible gases, made up almost entirely of methane. This loss is particularly important in ruminant animals in which it amounts to about 0.08 of the energy value of the food at the maintenance level of intake but falls to about 0.06 as the level of intake rises. Energy is also lost from the body in urine which contains organic waste products of no further direct use to the animal. The difference between the apparently digestible energy of the food and the sum of the methane and urinary energy losses is termed the 'metabolisable energy' (ME). It represents that portion of the food energy which can be utilised by the animal. On average about 0.81 of the digestible energy is metabolisable.

Animals produce heat continuously and lose it to their surroundings, even when fasting. If a fasted animal consumes food, its heat production increases, mainly due to the inefficiency with which absorbed nutrients are used by the body. Energy is also used in the mastication of the food and its propulsion through the alimentary canal and is dissipated as heat. In ruminant animals a further heat loss takes place through the activities of the micro-organisms of the gut. This may amount to 0.05 to 0.10 of the energy value of the food. The increase in heat production, resulting from the consumption and utilisation of food, is termed the 'heat increment' (HI) and since the heat is of no use to the animal, except in a particularly cold environment, it is regarded as an inevitable loss from the energy of the food. Deduction of the heat increment from the metabolisable energy gives the 'net energy' of the food, which represents that part of the food energy which is used by the animal for maintenance and production. The fate of food energy within the animal is illustrated in Figure 1.

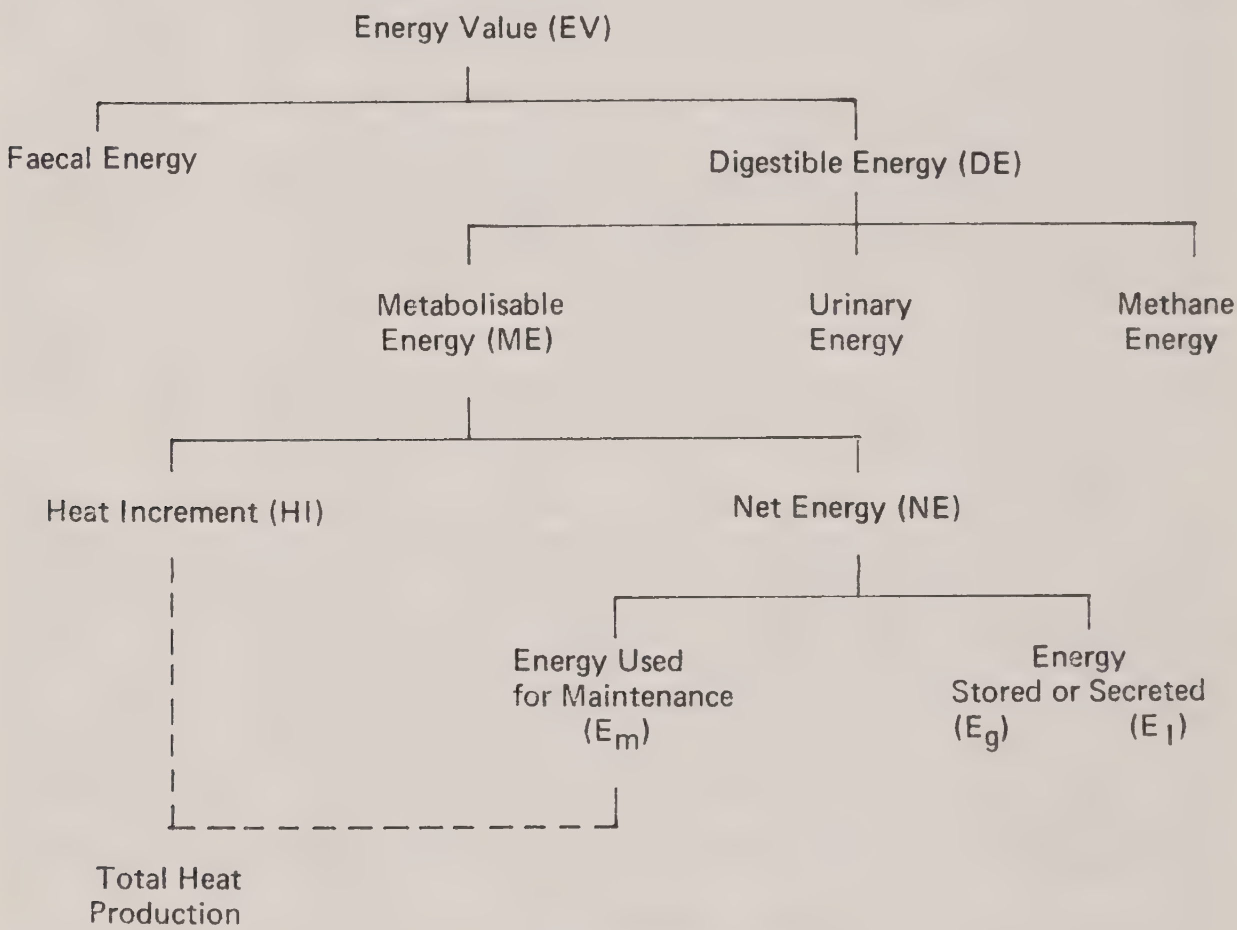


FIG. 1. Partitioning of food energy within the animal

An example of an actual energy balance is given in Table A.

**Table A**

*Partitioning of the energy of grass within the animal*

| | | | |
|---|---|---|---|
| Dry matter intake | | = 1·829 | kg |
| Energy intake | | = 35·0 | MJ |
| Faecal energy | | = 13·5 | MJ |
| Urinary energy | | = 1·2 | MJ |
| Methane energy | | = 2·4 | MJ |
| Heat increment | | = 7·0 | MJ |
| Digestible energy | $= \dfrac{35{\cdot}0 - 13{\cdot}5}{1{\cdot}829}$ | = 11·8 | MJ/kg |
| Metabolisable energy | $= \dfrac{35{\cdot}0 - (13{\cdot}5 + 1{\cdot}2 + 2{\cdot}4)}{1{\cdot}829}$ | = 9·8 | MJ/kg |
| Net energy | $= \dfrac{35{\cdot}0 - (13{\cdot}5 + 1{\cdot}2 + 2{\cdot}4 + 7{\cdot}0)}{1{\cdot}829}$ | = 6·0 | MJ/kg |

Wainman FW, Smith JB & Blaxter KL
*Proc. Nut. Soc.* (1971) 30, 23A

### The Use of the Metabolisable Energy Concept in the Feeding of Animals

A rationing system based on metabolisable energy involves a knowledge of the energy requirements of the animal, and the ability of the food to satisfy those requirements, in terms of metabolisable energy.

### Measurements of Metabolisable Energy

The energy supplied by foods (and the animal's requirements for energy) are measured in large respiration chambers or calorimeters. Measurements are made of the animal's heat production whilst intakes of food energy and energy losses in faeces, urine and methane are also recorded. Energy stored as fat and/or protein can also be calculated.

If a respiration chamber is not available, but faeces and urine losses are known from metabolism trials, the metabolisable energy of a food (MEF) can be calculated since the methane losses are assumed to be 0.08 of the energy value of the food.

If only digestibility data are available use may be made of the relationship:

$$\text{ME} = 0.81\ \text{DE} \tag{1}$$

Alternatively factors may be used to convert the digestible nutrients of a food to ME values and these summed to give the value for the food. The factors used in this bulletin are those proposed by workers at the Oskar Kellner Institute at Rostock, GDR:

Metabolisable Energy (MJ/kg) =

$$0.0152\ \text{DCP} + 0.0342\ \text{DEE} + 0.0128\ \text{DCF} + 0.0159\ \text{DNFE} \tag{2}$$

Where DCP = Digestible crude protein g/kg
DEE = Digestible ether extract g/kg
DCF = Digestible crude fibre g/kg
DNFE = Digestible nitrogen-free extractives g/kg

*Example 1*

| | *g/kg* | *Factor* | *ME (MJ)* |
|---|---|---|---|
| DCP | 90 | 0.0152 | 1.37 |
| DEE | 7 | 0.0342 | 0.24 |
| DCF | 221 | 0.0128 | 2.83 |
| DNFE | 354 | 0.0159 | 5.63 |
| | | | 10.07 |

Such approaches are conveniently used for concentrate foods since a chemical analysis can give the composition, and digestibility coefficients (as given in the tables of food composition) may be assumed for a given food with reasonable accuracy. With roughage foods this is not so because of the variability in their composition and the digestibilities of their constituents. With such foods it is usual to determine the level of a given constituent or constituents which may be related to the metabolisable energy in prediction equations. An example of this approach is the equation for predicting the metabolisable energy of hay from its content of modified acid detergent fibre and protein:

$$\text{ME (MJ/kg)} = 14.3 + 0.017\ \text{CP} - 0.019\ \text{MADF} \qquad (3)$$

where CP = Crude Protein in dry matter (g/kg)

MADF = Modified acid detergent fibre in dry matter (g/kg)

Details are given in Section V of recommended equations for various classes of foods.

The ME values of foods (designated MEF) are usually stated in terms of the ME concentration in the dry matter, MJ/kg.

### METABOLISABLE ENERGY OF THE RATION

The metabolisable energy of a ration (MER) is calculated by summing the contributions of the individual foods making up the diet, and is expressed in terms of MJ of ME.

### METABOLISABLE ENERGY CONCENTRATION OF RATIONS

The energy concentration (M/D) of a ration is the ME per kilogram of ration dry matter and is expressed as MJ/kg DM. Its calculation is a simple matter and is necessary for ration calculations for beef cattle and lambs.

*Example 2*

Calculation of M/D of a ration

| A ration consists of: | DMI (kg) | ME (MJ) |
|---|---|---|
| 6 kg hay, (850 g/kg DM, 8 MJ/kg DM) | 5.1 | 40.8 |
| 3 kg cereal, (830 g/kg DM, 13MJ/kg DM) | 2.5 | 32.4 |
| | 7.6 | 73.2 |

$$\text{Metabolisable Energy Concentration} = \frac{\text{Total ME of ration, (MER)}}{\text{Total dry matter intake, (DMI)}}$$

$$\textit{Thus } M/D = \frac{\text{MER}}{\text{DMI}} = \frac{73.2}{7.6} = 9.6\ \textit{MJ/kg}$$

## Metabolisable Energy Requirements

In order to formulate a requirement in terms of metabolisable energy the amount of net energy (NE) required must be known together with the efficiency (k) with which dietary metabolisable energy (ME) is used to satisfy that requirement. Then

$$k\,ME = NE$$

$$\text{or} \qquad \frac{NE}{k} = ME$$

Animals require energy for the maintenance of essential life processes such as respiration and the circulation of the blood. In addition, energy is required to provide the energy stored in various body tissues during growth and for products such as milk, and to actuate the synthetic processes involved in their production.

### MAINTENANCE

Energy used for maintenance is used for work and is dissipated as heat which is lost from the body. In the fasted animal this is derived from oxidation of body tissues and is termed the Fasting Metabolism (FM), representing the minimal requirement for energy to maintain the animal. It may be measured in a calorimeter, but in practice is usually estimated by means of equations (based on calorimetric measurements) such as

$$FM\ (MJ/day) = 5.67 + 0.061\ W \qquad (4)$$

where W = liveweight in kg

which is a general one for growing cattle. Depending upon the conditions under which animals are kept, an extra allowance of energy may be added to the fasting metabolism to allow for physical activity inseparable from the existence of the animal. This is referred to as an 'activity increment' and is usually about 0.1 of the fasting metabolism.

The efficiency with which ME is used for maintenance ($k_m$) is related to the energy concentration (M/D) of the ration and may be calculated as follows:

$$k_m = 0.55 + 0.016\ M/D \qquad (5)$$

where M/D = MJ per kg of dry matter.

Over a range of dietary ME concentrations in dry matter from 8 to 14 MJ/kg, $k_m$ varies from 0.68 to 0.77. In practice such dietary extremes are found only infrequently, and adoption of a single value of 0.72 for $k_m$ involves little error.

*Example 3*

Calculation of the ME requirement for maintenance, ($M_m$) of a 400 kg steer.

Fasting Metabolism, $FM = 5.67 + (0.061 \times 400) = 30.1$ MJ/day

$k_m = 0.72$

*ME Requirement,* $M_m = \dfrac{30.1}{0.72} = 42$ *MJ/day*

LIVEWEIGHT GAIN

The net energy requirement for gain ($E_g$) is the energy content of that gain and is the product of the weight of the gain (LWG) and its energy value ($EV_g$). For cattle, the energy value of gain is related to the liveweight in kg (W), and the energy stored in MJ ($E_g$), and may be calculated using the following equation:

$$EV_g\ (\mathrm{MJ/kg}) = 6.28 + 0.3\ E_g + 0.0188\ W \tag{6}$$

$$\text{Since } E_g = \mathrm{LWG} \times EV_g$$

$$\text{Then } E_g = \frac{\mathrm{LWG}\ (6.28 + 0.0188\ W)}{(1 - 0.3\ \mathrm{LWG})}\ \mathrm{MJ} \tag{7}$$

The efficiency of utilisation of ME for body gain ($k_g$) varies considerably for different types of food. These variations as they affect the total ration can be related to the energy concentration of the ration and $k_g$ may be calculated as follows:

$$k_g = 0.0435\ M/D \tag{8}$$

Thus $k_g$ can vary from about 0.30 to 0.60 as M/D varies from 7 to 14 MJ/kg

*Example 4*

Calculation of the ME requirement of a 400 kg steer gaining at 0.75 kg/day and fed a ration of M/D 10 MJ/kg.

ME required for maintenance, $M_m$ = 42 MJ/day (from previous example)

$$E_g = \frac{0.75\ [6.28 + (0.0188 \times 400)]}{[1 - (0.3 \times 0.75)]}$$

$$= 13.4\ \mathrm{MJ}$$

$$k_g = 0.0435 \times 10$$

$$= 0.435$$

ME required for body gain, $M_g = \dfrac{13.4}{0.435} = 30.8$ MJ

*Total daily requirement for ME* = 42 + 30.8 = *73 MJ*

*Example 5*

Prediction of liveweight gain of a 400 kg steer receiving 8.1 kg of a ration containing 900 g/kg of dry matter with an M/D of 10 MJ/kg.

Total ME intake per day $= 8.1 \times \dfrac{900}{1000} \times 10 = 72.9$ MJ

ME required for maintenance, $M_m$ = 42 MJ/day (from previous examples)

ME available for production, MEP = 72.9 − 42 = 30.9 MJ/day

$$k_g = 0.0435 \times 10$$

$$= 0.435$$

$$E_g = 30.9 \times 0.435 = 13.4\ \mathrm{MJ/day}$$

Energy value of Gain $EV_g = 6.28 + 0.3\ E_g + 0.0188\ W$ (6)

$$= 6.28 + (0.3 \times 13.4) + (0.0188 \times 400)$$

$$= 17.8\ \mathrm{MJ/kg}$$

$$\textit{Predicted Liveweight Gain, LWG} = \frac{E_g}{EV_g} = \frac{13.4}{17.8} = \textit{0.75 kg/day}$$

To obtain LWG directly use

$$LWG = \frac{E_g}{(6.28 + 0.3\ E_g + 0.0188\ W)} \qquad (9)$$

MILK PRODUCTION

The minimal requirement for energy for milk production ($E_l$) is the product of the weight of milk (Y) in kg and its energy value ($EV_l$). For cow's milk the energy value is calculated as follows:

$$EV_l\ (MJ/kg) = 0.0386\ BF + 0.0205\ SNF - 0.236 \qquad (10)$$

where BF = butter fat content (g/kg)
SNF = solids-not-fat content (g/kg)

The composition of milk is not always known and it may be necessary to adopt averages for different breeds. Alternatively, milk production may be related to a base of solids-corrected milk (SCM) with a butterfat of 40 g/kg and a solids-not-fat content of 89 g/kg, or to an average milk having a butterfat of 36 g/kg and a solids-not-fat content of 86 g/kg

The efficiency of utilisation of ME for milk production ($k_l$) is related to the ME concentration of the diet. Over the range of concentrations normally encountered with dairy cow diets the variation in $k_l$ is not great and little error is incurred by the adoption of a single value of 0.62. The ME requirement for the production of 1 kg of milk is given by

$$\frac{EV_l}{0.62} \text{ or } 1.61\ EV_l$$

and the ME required ($M_l$) for the production of Y kg of milk is given by

$$M_l(MJ) = 1.61\ EV_l \times Y \qquad (11)$$

MOBILISATION OF BODY RESERVES

Energy other than that of the food may become available for milk production owing to the mobilisation of the body reserves of the lactating animal. The energy value of body tissue thus mobilised is about 20 MJ/kg. This can be used for milk production with an efficiency of 0.82. Hence 1 kg body weight loss would produce $20 \times 0.82 = 16.4$ MJ as milk, equivalent to 5.2 kg solids corrected milk.

ME is used for body gain in the *lactating* dairy cow with the same efficiency, 0.62, as for lactation . A gain in weight of 1 kg thus increases the animal's requirement for ME by

$$\frac{20}{0.62} = 32.3 \text{ MJ}$$

This high efficiency for gain, ($k_g$) of 0.62, only applies whilst cows are lactating. Dry cows gain weight less efficiently and the same values of $k_g$ as for growing cattle are suggested, as in Section III of this bulletin and Example 4 of this section.

PREGNANCY

The pregnant animal requires energy to maintain itself and the developing foetus. In addition, energy is stored in the foetus and associated membranes and in accrued uterine tissues, and is required for the syntheses involved in their production. The energy stored daily in the uterus and uterine contents increases exponentially throughout pregnancy and is of considerable significance in the final stages. For cattle the daily energy deposition ($E_c$) may be estimated by equations such as the following:

$$\text{Uterine Deposition of Energy, } E_c = 0.03\ e^{0.0174t}\ (\text{MJ/day}) \tag{12}$$

where t = the number of days after conception

and e = 2.718, the base of the natural logarithms.

Heat production in pregnant animals is greater than expected for non-pregnant animals of similar weights. The increased heat production is termed the 'Heat Increment of Gestation' (HIG) and may be calculated for cattle as follows:

$$\text{Heat Increment of Gestation, HIG} = 0.904\ e^{0.01t}\ (\text{MJ/day}) \tag{13}$$

where t = the number of days after conception

and e = 2.718.

About half the heat increment of gestation arises from the synthetic processes producing the foetus and associated structures. The remainder arises from the energy used for foetal maintenance and the increase in maternal fasting metabolism occuring in pregnancy.

Thus the ME requirement for the growth of the foetus and associated structures will be the sum of the energy stored, ($E_c$) plus half the heat increment of gestation, i.e., $E_c + \dfrac{\text{HIG}}{2}$ MJ/day.

The energy for foetal and increased maternal maintenance may be assumed to be provided from dietary ME with the usual efficiency of 0.72 and the ME requirement is then

$$\frac{\text{HIG}}{2 \times 0.72}$$

The extra ME requirement for pregnancy will therefore be

$$E_c + \frac{\text{HIG}}{2} + \frac{\text{HIG}}{2 \times 0.72}\ \text{MJ/day}$$

which becomes

$$\text{ME requirement} = E_c + 1.19\ \text{HIG} \tag{14}$$

Values for $E_c$ and HIG can be obtained from equations (12) and (13), and values for ($E_c$ + 1.19 HIG) are given by the equation

$$E_c + 1.19\ \text{HIG} = 1.08\ e^{0.0106t}\ \text{MJ/day} \tag{15}$$

where t = number of days after conception

and e = 2.718

The total ME requirement of a pregnant cow will therefore be:

$$M_m + 1.08\ e^{0.0106t}\ \text{MJ/day} \tag{16}$$

*Example 6*

Calculation of the ME requirement of a 500 kg cow producing a 40 kg calf at birth, at 250 days after conception.

ME required for normal maternal maintenance, $M_m = 50.2$ MJ/day

Heat Increment of Gestation, HIG $= 0.904\ e^{0.01 \times 250} = 11.0$ MJ/day

Energy stored in foetus $E_c = 0.03\ e^{0.0174 \times 250} = 2.3$ MJ/day

$$\begin{aligned} \textit{ME requirement} &= M_m + E_c + 1.19\ \text{HIG} \\ &= 50.2 + 2.3 + (1.19 \times 11.0)\ \text{MJ/day} \\ &= \mathit{65.6\ MJ/day} \end{aligned}$$

## The Use of a Net Energy System for Growing Animals

The metabolisable energy system provides a suitable method for predicting performance in growing animals but does not allow easy, convenient formulation of rations. To formulate a ration it is necessary to know the metabolisable energy requirements for growth and therefore the metabolisable energy concentration of the ration. Obviously this cannot be known until the ration is formulated. The problem can be overcome by using various procedures but a simpler method is to eliminate the dependence of requirement upon the metabolisable energy concentration of the ration. This can be achieved by using a net energy requirement. The net energy values of foods must then be known if rations are to be formulated.

### NET ENERGY REQUIREMENTS

The net energy requirements for maintenance ($E_m$) and growth ($E_g$) have already been discussed and may be calculated as

$$E_m\ (\text{MJ/day}) = 5.67 + 0.061\ W \qquad (4)$$

$$E_g\ (\text{MJ/day}) = \frac{\text{LWG}\ (6.28 + 0.0188\ W)}{(1 - 0.3\ \text{LWG})} \qquad (7)$$

In a general sense $E_g$ may be replaced by $E_p$, the net energy required for production.

### NET ENERGY VALUES OF FOODS

The net energy of a food for maintenance ($NE_m$) may be calculated as:

$$NE_m\ (\text{MJ/kg}) = M_m \times k_m$$

and for production

$$NE_p\ (\text{MJ/kg}) = M_p \times k_p$$

In a productive situation the net energy of a food is a combination of $NE_m$ and $NE_p$ i.e., $NE_{mp}$, the net energy for maintenance and production, which may be calculated as:

$$NE_{mp}\ (\text{MJ/kg}) = M_{mp} \times k_{mp} \qquad (17)$$

If we consider two foods of MEF 14 (1) and 10 (2) given at a single level of production we have a situation illustrated in Fig. 2.

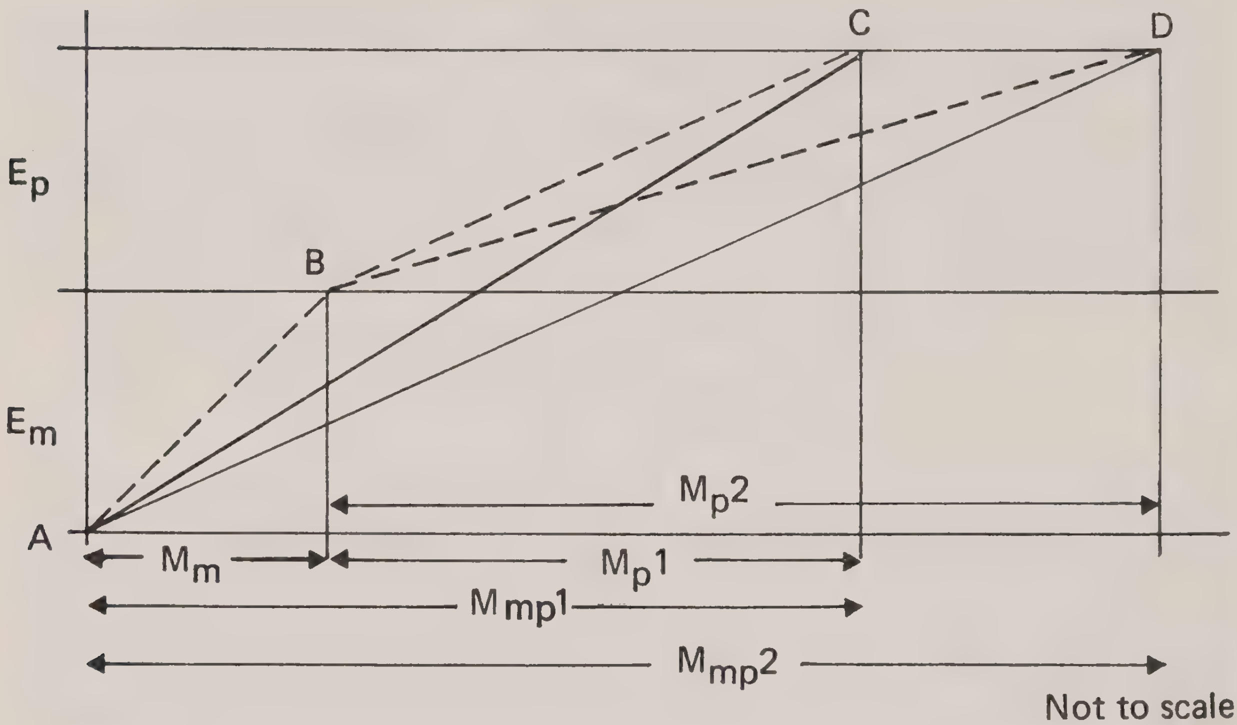


FIG. 2. Net energies of two foods at the same animal production level

The efficiency of utilisation of dietary metabolisable energy for maintenance ($k_m$) for both foods is the slope of the line AB. The slope of line BC gives the efficiency of utilisation of dietary metabolisable energy for production ($k_p$) for a food of M/D 14 while the slope of the line BD gives $k_p$ for a food of M/D 10. The efficiencies of utilisation for the combined functions of maintenance and growth ($k_{mp}$) are given by the slopes of AC and AD for the foods of M/D 14 and 10 respectively. This can be expressed as

$$k_{mp} = \frac{E_m + E_p}{M_{mp}} \tag{18}$$

where $E_m$ = net energy for maintenance as given in equation (4)

$E_p$ = net energy for body gain given by equation (7)

and $M_{mp}$ = the metabolisable energy required for maintenance and production.

On the other hand, if we consider the situation of a single food with an M/D of say 10 given at two levels of production we have the situation illustrated in Fig. 3.

$k_{mp}$ at a level of production one and a half times $E_m$ is given by the slope of the line AC and for a level of twice $E_m$ by the slope of AD.

It is clear that $k_{mp}$ varies with metabolisable energy concentration of the food and with level of production, and it follows that the net energies of foods will be different for different productive situations and must be calculated afresh each time.

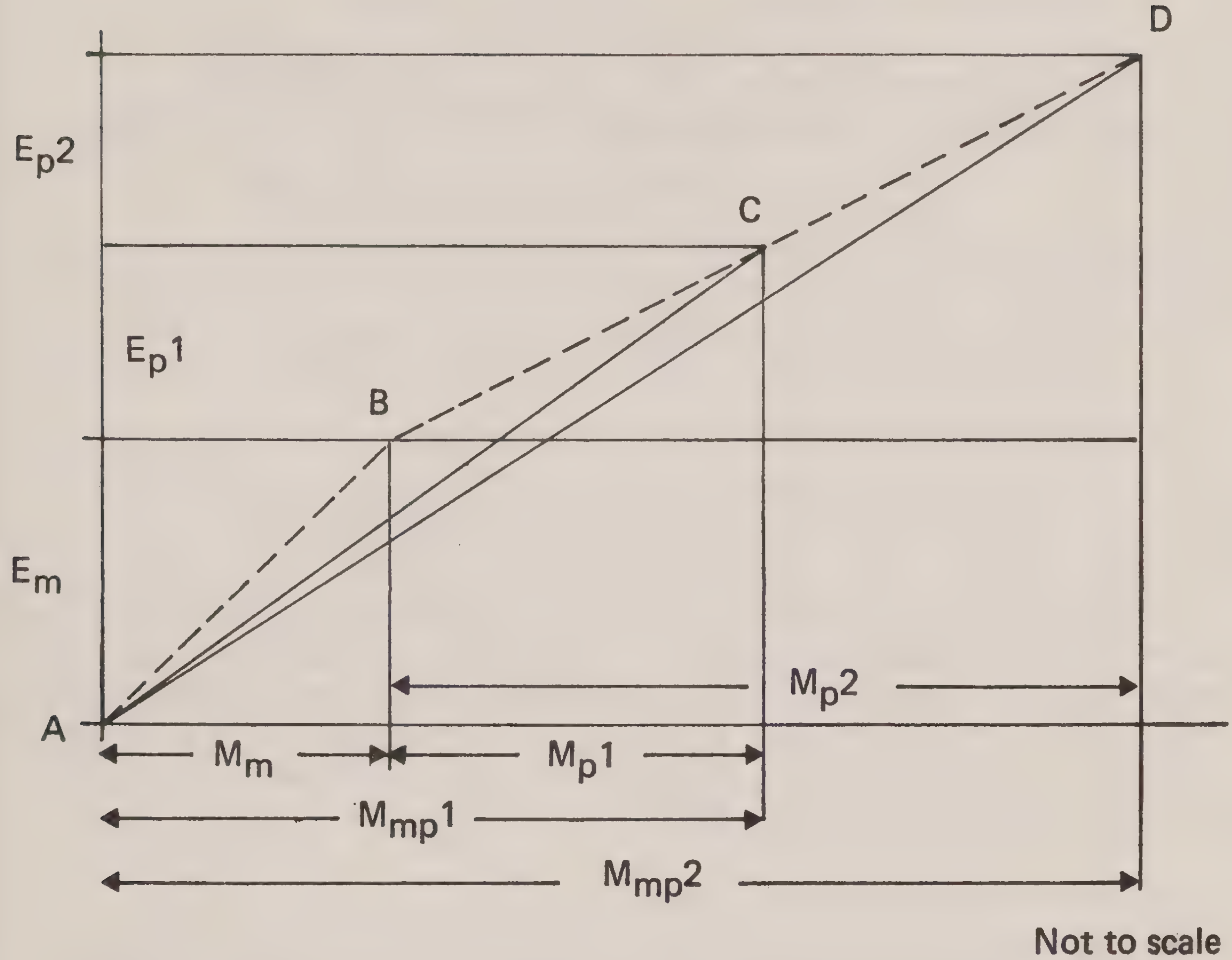


FIG. 3. Net energies of the same food at two levels of animal production

*Example 7*

Formulation of a ration from hay (MEF 8.5 MJ/kg DM)

and compound (MEF 13 MJ/kg DM)

for a 400 kg steer growing at 0.75 kg/day.

$$E_m = 30.1 \text{ MJ} \qquad (4)$$

$$E_p = 13.4 \text{ MJ} \qquad (7)$$

If only hay were fed, the theoretical ME requirement for a ration of M/D 8.5 MJ/kg DM would be 78 MJ, i.e.,

$$M_{mp} \text{ for hay} = 78.0 \text{ MJ}$$

$$\text{hence} \quad k_{mp} \text{ for hay} = \frac{30.1 + 13.4}{78} = 0.558$$

$$\text{and} \qquad NE_{mp} = 8.5 \times 0.558 = 4.74 \text{ MJ/kg DM}$$

Similarly if only compound were fed, the theoretical ME requirement would be

$$M_{mp} \text{ for the compound} = 65.5 \text{ MJ}$$

$$k_{mp} \text{ for the compound} = \frac{30.1 + 13.4}{65.5} = 0.664$$

$$NE_{mp} \text{ for the compound} = 13.0 \times 0.66 = 8.63 \text{ MJ/kg DM}$$

$$\text{Total net energy requirement } (E_{mp}) = 30.1 + 13.4 = 43.5 \text{ MJ/day}$$

$$\textit{Hay required} = \frac{43.5}{4.74} = \textit{9.2 kg dry matter}$$

$$\textit{Compound required} = \frac{43.5}{8.63} = \textit{5.0 kg dry matter}$$

*Hay required to feed with 3 kg compound dry matter*

$$= \frac{43.5 - (3.0 \times 8.63)}{4.74} = \textit{3.7 kg dry matter}$$

Such calculations are laborious and time consuming and are only acceptable when sophisticated computational facilities are available. In the absence of such facilities considerable improvement can be achieved by making use of the fact that $NE_{mp}$ is constant for foods of a particular M/D at a particular production level. The effect of the latter can be quantified by relating it to the animal production level (APL).

### ANIMAL PRODUCTION LEVEL

This term was first suggested by MacHardy in 1965, who defined it as

$$\text{Animal Production Level, APL} = \frac{E_m + E_p}{E_m} \text{ or } 1 + \frac{E_p}{E_m} \qquad (19)$$

This approach has been called 'scaling by fasting metabolism' and resembles the use of 'x times maintenance' as a method of describing plane of nutrition irrespective of body size. Animals at maintenance have an APL value of 1.0 since by definition $E_p = 0$ at maintenance.

Tables of $NE_{mp}$ values for foods of different metabolisable energy concentrations at different APL values may be constructed. The APL for a given situation may then be calculated and used, along with the M/D values of the foods available, to enter the tables of $NE_{mp}$ values. These may then be used as shown in *Example 7*. The use of the tables is discussed in detail in Section III of this bulletin.

## Safety Margins

The Ministry of Agriculture, Fisheries and Food Energy Working Party which reported in 1972 recommended that ME requirements should be increased by 5% overall to make them ME 'allowances'. No firm statistical basis was given for this safety margin, but considerations of the known variability of fasting metabolism measurements ($\pm$ 10%) and the variations in the ME values of foods were felt to justify such a recommendation. In the sections on dairy cattle, beef cattle and sheep which follow, a safety margin has been included in all the tables. This should be borne in mind when comparing these sections with this introductory section where no safety margins were included in the examples and calculations.

# SECTION II

## Use of the Metabolisable Energy System for dairy cows

### Calculation of Metabolisable Energy Allowances

As discussed in Section I, the use of the ME system for dairy cattle involves the separate calculation of the maintenance and production allowances which are then summed to give a total ME allowance. This figure may have to be modified in the light of weight changes taking place in the animal.

METABOLISABLE ENERGY ALLOWANCES FOR MAINTENANCE

The net energy requirement for maintenance is the fasting metabolism plus any activity allowance deemed necessary. Fasting metabolism for the cow may be taken as 0.36 MJ/kg $W^{0.73}$, which with a 10% activity allowance gives a net energy requirement ($E_m$) of 0.396 MJ/kg $W^{0.73}$.

The efficiency of utilisation of ME for maintenance ($k_m$) is assumed to be constant at 0.72, and the ME requirement for maintenance $M_m$ can be calculated from

$$M_m = \frac{E_m}{k_m} = \frac{0.396 \text{ MJ/kg } W^{0.73}}{0{\cdot}72}$$

$$= 0.55 \text{ MJ/kg } W^{0.73}$$

Addition of a 5% safety margin gives a total allowance of 0.58 MJ/kg $W^{0.73}$. There is little loss of precision if a simple linear equation is used, so that ME allowances for maintenance ($M_m$) are given by

$$M_m = 8.3 + 0.091 \text{ W} \qquad (20)$$

where $M_m$ = maintenance allowance in MJ
and W = liveweight in kg

The maintenance allowance $M_m$, for cows of various liveweights are shown in Table 1.

**Table 1**

*Daily maintenance allowance of ME for beef cattle and dairy cows*

| Body weight (kg) | MJ/head |
|---|---|
| 100 | 17 |
| 150 | 22 |
| 200 | 27 |
| 250 | 31 |
| 300 | 36 |
| 350 | 40 |
| 400 | 45 |
| 450 | 49 |
| 500 | 54 |
| 550 | 59 |
| 600 | 63 |

(including safety margin)
Based on $M_m = 8{\cdot}3 + 0{\cdot}091$ W

METABOLISABLE ENERGY ALLOWANCES FOR MILK PRODUCTION

The net energy requirement for milk production ($E_l$) is the energy of the milk secreted. This depends upon the milk yield (Y) and the energy value of the milk ($EV_l$). The energy value of the milk secreted is calculated from the equation

$$EV_l = 0.0386\ BF + 0.0205\ SNF - 0.236 \tag{10}$$

where $EV_l$ is the energy value of the milk secreted in MJ/kg

and BF and SNF are in g/kg of milk

The efficiency of utilisation of ME for milk production ($k_l$) has been assumed to be constant at 0.62. The ME requirement for milk production, ($M_l$) will be given by $\frac{EV_l}{0.62}$, which with the inclusion of a 0·05 safety margin becomes

$$M_l = 1.694\ EV_l \text{ MJ/kg milk} \tag{21}$$

The ME allowances for the production of 1 kg of milk from different breeds of cow are tabulated in Table 2.

**Table 2**

*ME allowances for* 1 *kg milk*

| Type of milk | BF (g/kg) | SNF (g/kg) | Energy value $EV_l$, (MJ/kg) | ME allowance $M_l$, (MJ/kg) |
|---|---|---|---|---|
| Channel Island | 48 | 91 | 3·482 | 5·90 |
| Shorthorn | 36 | 87 | 2·937 | 4·98 |
| Ayrshire | 37 | 88 | 2·996 | 5·08 |
| Friesian | 35 | 86 | 2·878 | 4·88 |
| Average | 36 | 86 | 2·917 | 4·94 |
| Solids corrected | 40 | 89 | 3·133 | 5·31 |

(including safety margin)

Based on $M_l = 1{\cdot}694\ EV_l$

If the butter fat (BF) and solids-not-fat (SNF) values for the milk are known, the ME allowance for 1 kg of milk of any quality can be found in Table 3. (Note: BF and SNF values are g/kg = 10 × BF% or SNF%)

*Example 8*

Calculation of the ME allowance for a Friesian cow weighing 600 kg giving 20 kg milk at 36 g/kg BF and 85 g/kg SNF.

The ME allowance for maintenance $M_m$ = 63 MJ (Table 1)

Milk of 36 g/kg BF and 85 g/kg SNF requires 4.9 MJ/kg of milk (Table 3).

Hence a milk yield of 20 kg requires 20 × 4.9 = 98 MJ ME

So $M_l$ required is 98 MJ

*Total ME allowance* = 63 + 98 = *161 MJ/day* (Table 4).

**Table 3**

*Metabolisable energy allowance (MJ) to produce 1 kg milk of varying composition*

| SNF content (g/kg) | Fat content of milk (g/kg) 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 84 | 4·48 | 4·61 | 4·74 | 4·87 | 5·00 | 5·13 | 5·26 | 5·39 | 5·52 | 5·65 | 5·79 | 5·92 |
| 85 | 4·51 | 4·64 | 4·77 | 4·90 | 5·04 | 5·17 | 5·30 | 5·43 | 5·56 | 5·69 | 5·82 | 5·95 |
| 86 | 4·55 | 4·68 | 4·81 | 4·94 | 5·07 | 5·20 | 5·33 | 5·46 | 5·59 | 5·72 | 5·85 | 5·99 |
| 87 | 4·58 | 4·71 | 4·84 | 4·98 | 5·10 | 5·24 | 5·37 | 5·50 | 5·63 | 5·76 | 5·89 | 6·02 |
| 88 | 4·62 | 4·75 | 4·88 | 5·01 | 5·14 | 5·27 | 5·40 | 5·53 | 5·66 | 5·79 | 5·92 | 6·05 |
| 89 | 4·65 | 4·78 | 4·91 | 5·04 | 5·17 | 5·31 | 5·44 | 5·57 | 5·70 | 5·83 | 5·96 | 6·09 |
| 90 | 4·69 | 4·82 | 4·95 | 5·08 | 5·21 | 5·34 | 5·47 | 5·60 | 5·73 | 5·86 | 5·99 | 6·12 |
| 91 | 4·72 | 4·85 | 4·98 | 5·11 | 5·24 | 5·37 | 5·51 | 5·64 | 5·77 | 5·90 | 6·03 | 6·16 |
| 92 | 4·76 | 4·89 | 5·02 | 5·15 | 5·28 | 5·41 | 5·54 | 5·67 | 5·80 | 5·93 | 6·06 | 6·19 |
| 93 | 4·79 | 4·92 | 5·05 | 5·18 | 5·31 | 5·44 | 5·57 | 5·71 | 5·84 | 5·97 | 6·10 | 6·23 |
| 94 | 4·82 | 4·96 | 5·09 | 5·22 | 5·35 | 5·48 | 5·61 | 5·74 | 5·87 | 6·00 | 6·13 | 6·26 |
| 95 | 4·86 | 4·99 | 5·12 | 5·25 | 5·38 | 5·51 | 5·64 | 5·77 | 5·91 | 6·04 | 6·17 | 6·30 |

(Including safety margin)

Milk of average composition — Solids corrected milk (SCM)

SIGNIFICANCE OF LIVEWEIGHT CHANGE IN THE CALCULATION OF ME ALLOWANCE

If a cow's ration is deficient in energy, the deficit is made up from the body reserves of the cow with a resultant loss in weight. In Section I an outline was given of the quantitative aspects of this important question.

Briefly, body tissue has an energy value of 20 MJ/kg and can be used with an efficiency of 0.82 for milk production. Thus each kg of tissue mobilised will allow the secretion of $20 \times 0.82 = 16.4$ MJ as milk. This is equivalent to a dietary ME of

$$\frac{16.4 \times 1.05}{0.62} = 28 \text{ MJ (including safety margin)}$$

To summarise: *1 kg liveweight loss equals 28 MJ of dietary ME.*

*Example 8 continued*

The Friesian cow is known to be losing 0.5 kg per day whilst producing the 20 kg milk.

From *Example 8*

Total ME allowance (no weight change) = 161 MJ/day

ME available from liveweight loss ($M_g$) = $28 \times 0.5 = 14$ MJ/day

*Total ME allowance* = 161 − 14

= *147 MJ/day* (Table 4)

Body tissue is laid down with a higher efficiency ($k_g$) in the lactating compared with the non-lactating animal, and has a similar value to $k_l$ of 0.62. The dietary ME allowance for gain is therefore

$$M_g = \frac{20}{0.62} \times 1.05 = 34 \text{ MJ/kg gain (including safety margin)}$$

*so ME allowance for 1 kg liveweight gain is 34 MJ dietary ME*

Allowances for body gain have to be added to those for maintenance and milk production in the calculation of ME allowances for animals gaining weight.

*Example 8 continued*

If the cow in this example is gaining 0.5 kg/day instead of losing it,

total ME allowance (no weight change) = 161 MJ/day

ME allowance for weight gain = 0.5 × 34 = 17 MJ/day

*Total ME allowance* = 161 + 17 = *178 MJ/day* (Table 4)

DAILY ME ALLOWANCES FOR DAIRY COWS

Suggested daily allowances of ME for three common breeds of dairy cattle are given in Table 4. They include an adjustment for liveweight change, but it must be remembered that the data can only be used to predict milk yield or liveweight change, if the other is known.

**Table 4**

*Daily ME allowances for three breeds of dairy cattle (MJ/head)*

| Breed | Liveweight change | Maintenance | Milk yield kg/day | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 5 | 10 | 15 | 20 | 25 | 30 | 35 |
| JERSEY | | | | | | | | | |
| 363 kg | Losing 0·5 kg/day | — | 58 | 88 | 118 | 149 | 180 | | |
| 49 g/kg BF | No weight change | 41 | 72 | 102 | 132 | 163 | 194 | | |
| 95 g/kg SNF | Gaining 0·5 kg/day | — | 89 | 119 | 149 | 180 | 211 | | |
| AYRSHIRE | | | | | | | | | |
| 500 kg | Losing 0·5 kg/day | — | 66 | 92 | 118 | 144 | 169 | 195 | |
| 38 g/kg BF | No weight change | 54 | 80 | 106 | 132 | 158 | 183 | 209 | |
| 89 g/kg SNF | Gaining 0·5 kg/day | — | 97 | 123 | 149 | 175 | 200 | 226 | |
| FRIESIAN | | | | | | | | | |
| 590 kg | Losing 0·5 kg/day | — | 73 | 97 | 122 | 147 | 172 | 196 | 221 |
| 36 g/kg BF | No weight change | 62 | 87 | 111 | 136 | 161 | 186 | 210 | 235 |
| 86 g/kg SNF | Gaining 0·5 kg/day | — | 104 | 128 | 153 | 178 | 203 | 227 | 252 |

(including safety margin)

Table 4 can be used to check the energy requirement of a cow whose milk yield is known and to quantify the effects of any energy deficits or surpluses. When formulating rations it will be important to consider the stage of lactation and desired liveweight change, as well as expected milk yield. A typical liveweight change pattern for a lactation is given later in this section.

METABOLISABLE ENERGY ALLOWANCES FOR PREGNANCY

Details were given in Section I of the basis for calculation of the ME allowances for pregnancy. These can readily be calculated from the equation

$$\text{ME for maintenance and pregnancy} = M_m + 1.13\ e^{0.0106t}\ \text{MJ/day} \qquad (16)$$

where $t$ = number of days pregnant

and $e$ = 2.718, the base of natural logarithms.

The calculated ME allowances are less than 5 MJ above maintenance up to the fifth month of pregnancy, hence allowances are shown in Table 5 from the sixth month of pregnancy only.

**Table 5**

*Daily ME allowances for pregnancy in cattle (MJ/head)*

| Liveweight (kg) | Month of pregnancy | | | |
|---|---|---|---|---|
| | 6 | 7 | 8 | 9 |
| 350 | 48 | 51 | 55 | 60 |
| 400 | 52 | 55 | 59 | 65 |
| 450 | 57 | 60 | 64 | 69 |
| 500 | 61 | 64 | 68 | 74 |
| 550 | 66 | 69 | 73 | 78 |
| 600 | 71 | 73 | 77 | 83 |
| 650 | 75 | 78 | 82 | 87 |
| 700 | 80 | 83 | 86 | 92 |

(including safety margin)

Based on $M_{mp} = M_m + 1{\cdot}13e^{\ 0{\cdot}0106t}$

where $t$ = number of days pregnant

## Appetite Limits for Dairy Cows

Sound ration formulation for dairy cattle requires that some estimate of their probable dry matter appetite under the conditions in which they are housed and fed be known. Appetite is influenced by body size and to some extent by milk yield and stage of lactation. There are a number of properties of foods which affect dry matter intake such as digestibility, processing and method of conservation of forage, as well as the nature of the feeding system and timing of feeds. It is difficult to systematise these factors satisfactorily, and estimates of intake have to rely largely on the experience and judgment of the feeder. The following equation has been

found generally useful for mid and late lactation cows fed on mixed diets:

$$\text{DMI} = 0.025\ \text{W} + 0.1\ \text{Y} \qquad (22)$$

where DMI = dry matter intake, kg/day
W = liveweight, kg
Y = milk yield, kg/day

In early lactation (the first 10 weeks) appetite is known to be reduced, probably by 2-3 kg/day below the values given by this equation. Estimates of probable dry matter intakes for cows of different weights and producing different quantities of milk are given in Table 6.

**Table 6**

*Probable dry matter intakes of cows in mid and late lactation (kg/day)*

| Liveweight, W (kg) | Milk yield, Y (kg/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| 350 | 9·3 | 9·8 | 10·3 | 10·8 | 11·3 | 11·8 | | |
| 400 | 10·5 | 11·0 | 11·5 | 12·0 | 12·5 | 13·0 | | |
| 450 | 11·8 | 12·3 | 12·8 | 13·3 | 13·8 | 14·3 | 14·8 | |
| 500 | 13·0 | 13·5 | 14·0 | 14·5 | 15·0 | 15·5 | 16·0 | |
| 550 | 14·3 | 14·8 | 15·3 | 15·8 | 16·3 | 16·8 | 17·3 | 17·8 |
| 600 | 15·5 | 16·0 | 16·5 | 17·0 | 17·5 | 18·0 | 18·5 | 19·0 |
| 650 | 16·8 | 17·3 | 17·8 | 18·3 | 18·8 | 19·3 | 19·8 | 20·3 |
| 700 | 18·0 | 18·5 | 19·0 | 19·5 | 20·0 | 20·5 | 21·0 | 21·5 |

Based on DMI (kg/day) = 0·025 W + 0·1 Y

**Note.** In first 6 weeks of lactation, reduce values in Table 6 by 2-3 kg DMI per day

## Checking the Adequacy of a Given Dairy Cow Ration

In order to do this the following data are needed:

(a) cow's liveweight, W (kg)

(b) cow's milk yield, Y (kg)

(c) cow's milk quality, BF and SNF, (g/kg)

(d) total ME supplied by the ration, MER (MJ)

and it is necessary to calculate:

(e) ME required for maintenance, $M_m$ (MJ)

(f) ME available for production MEP (MJ)

(g) ME required for known milk production $M_l$ (MJ)

(h) the difference if any between MEP and $M_l$

and to interpret this difference $M_g$ in terms of liveweight change.

*Example 9*

A Friesian heifer in late lactation weighs 500 kg, has a milk yield of 10 kg, and is being fed a ration of

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 3 kg hay, | (850 g/kg DM and 8 MJ/kg DM) | 2.55 | 20.4 |
| 30 kg maize silage, | (250 g/kg DM and 10 MJ/kg DM) | 7.50 | 75.0 |
| 3 kg compound, | (860 g/kg DM and 12.5 MJ/kg DM) | 2.58 | 32.3 |
| | | 12.63 | 127.7 |

Ration ME, MER = 128 MJ

Probable dry matter intake, DMI = (0.025 × 500) + (0.1 × 10) kg
= 13.5 kg/day

hence the ration is feasible.

ME for maintenance, $M_m$ = 54 MJ (Table 1)

ME for production, MEP = 128 − 54 = 74 MJ

ME for milk production, $M_l$ = 10 × 4.9 = 49 MJ (Table 2)

*Difference,* $M_g$ = + *25 MJ*

1 kg liveweight gain requires 34 MJ per day

Therefore it is concluded that this heifer is *gaining weight at a rate of*

$$\frac{25}{34} = 0.74 \ kg/day$$

**Formulation of Rations to Support Desired Levels of Milk Production**

The following information is required before proceeding:

(a) liveweight of the cow, W (kg)
(b) desired liveweight change, ± kg/day
(c) milk yield expected, Y (kg)
(d) milk quality, BF and SNF (g/kg)
(e) ME content of the available foods (MJ/kg)
(f) dry matter content of the foods (g/kg)
(g) dry matter appetite of the cow (kg/day)

and to calculate:

(h) ME allowance for maintenance, $M_m$ (MJ)
(i) ME allowance for production, $M_p$ (MJ)
(j) total ME allowance, $M_m + M_p$ (MJ)
(k) total DM and ME supplied by the foods making up the ration and to compare these with (j) and (g)

*Example 10*

An Ayrshire cow of 500 kg is expected to produce 25 kg milk, and a liveweight loss of not more than 0.5 kg/day would be acceptable. BF is 38 g/kg and SNF is 89 g/kg and appetite expected to be 15 kg DM.

The foods available are: Grass silage, 200 g/kg DM and 9 MJ/kg DM
Rolled barley, 850 g/kg DM and 13.7 MJ/kg DM
Dairy compound, 860 g/kg DM and 12.5 MJ/kg DM

ME for maintenance $M_m = 54$ MJ (Table 1)
ME for production $M_p = 25 \times 5.17 = 129$ MJ (Table 3)
Contribution from
liveweight loss, $M_g = 0.5 \times 28 = 14$ MJ

*Minimum ME required* $= M_m + M_l + M_g = 54 + 129 - 14$
$= 169$ *MJ/day* (Table 4)

*Trial Ration*

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 40 kg silage, (200 g/kg DM, 9 MJ/kg DM) | 8.0 | 72.0 |
| 4 kg barley, (850 g/kg DM, 13.7 MJ/kg DM) | 3.4 | 46.6 |
| 6 kg compound, (860 g/kg DM, 12.5 MJ/kg DM) | 5.2 | 64.5 |
| | 16.6 | 183.1 |

This ration meets the full energy demand of the cow, 183 MJ (Table 4), and no liveweight loss would be likely. Since, however, the dry matter appetite was stated to be only 15 kg, the ration will not be fully consumed. If the silage intake is reduced by 8 kg/day the ration becomes

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 32 kg silage, (200 g/kg DM, 9 MJ/kg DM) | 6.4 | 57.6 |
| 4 kg barley, (850 g/kg DM, 13.7 MJ/kg DM) | 3.4 | 46.6 |
| 6 kg compound, (860 g/kg DM, 12.5 MJ/kg DM) | 5.2 | 64.5 |
| | 15.0 | 168.7 |

The total ME required is now close to the minimum of 169 MJ allowing for 0.5 kg liveweight loss per day, an acceptable, and probably unavoidable figure. It must be remembered however that prediction of dairy cattle performance from a knowledge of the dietary energy input is fraught with difficulties, because cows have two alternative forms of output, milk and liveweight gain (or loss). The partitioning of production energy between liveweight and milk is difficult to quantify. Several factors which influence it have been identified, e.g., early lactation feeding level, current stage of lactation, nature of the diet. If the dietary intake and milk yield of a cow are known, calculations will indicate whether that cow's energy requirements are being met adequately, as shown earlier in this Section.

### RAPID FORMULATION OF FORAGE AND COMPOUND FOOD RATIONS

In the case of two component food systems i.e. forage and compound food only, the energy concentration of the ration (M/D) can be used as a method of calculating rations which meet both dry matter appetite limits and energy allowances.

By definition, ration energy concentration, $M/D = \dfrac{\text{ME allowance (MJ)}}{\text{DM intake (kg)}}$

In *Example 10*, $M/D = \dfrac{168.7}{15} = 11.2$ MJ/kg DM

The results of using equation (22) for dry matter intake values (Table 6), and the values for the ME allowances of cows (Table 4), to calculate minimum M/D values for rations, are given in Table 7.

**Table 7**

*Minimum metabolisable energy concentrations of diets for cows, M/D (MJ/kg DM)*

| Breed | Milk yield (kg/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 |
| JERSEY | | | | | | | | |
| − 0·5 kg/day | — | (5·9) | (8·6) | 11·1 | 13·4 | | | |
| No change | (4·6) | (7·5) | 10·2 | 12·6 | | | | |
| + 0·5 kg/day | — | (9·3) | 11·8 | 14·1 | | | | |
| AYRSHIRE | | | | | | | | |
| − 0·5 kg/day | — | (5·0) | (6·7) | (8·3) | 9·8 | 11·2 | 12·5 | |
| No change | (4·3) | (6·1) | (7·8) | (9·4) | 10·8 | 12·2 | 13·5 | |
| + 0·5 kg/day | — | (7·4) | (9·1) | 10·6 | 12·0 | 13·3 | | |
| FRIESIAN | | | | | | | | |
| − 0·5 kg/day | — | (4·7) | (6·1) | (7·4) | (8·7) | 9·8 | 10·9 | 12·0 |
| No change | (4·2) | (5·7) | (7·1) | (8·4) | (9·6) | 10·7 | 11·8 | 12·8 |
| + 0·5 kg/day | — | (6·8) | (8·1) | (9·4) | 10·6 | 11·7 | 12·7 | |

( ) indicates theoretical value only, appetite limits on poor quality forage make ration infeasible.

If only silage (9 MJ/kg DM) and compound food (12.5 MJ/kg DM) are available, the weight of the two foods necessary to give an M/D of 11.2 MJ/kg can be calculated using the formula

$$FD = \frac{DMI\ (MC - M/D)}{(MC - MF)} \qquad (23)$$

where FD is forage dry matter intake, kg,
DMI is dry matter intake, kg,
MC is ME of compound DM, MJ/kg,
MF is ME of forage DM, MJ/kg.

In this example $FD = \dfrac{15\ (12.5 - 11.2)}{(12.5 - 9)} = 5.6$ *kg forage dry matter*

*Compound dry matter intake, CD* = DMI − FD = 15 − 5.6 = *9.4 kg*
Thus a diet of 5.6 kg silage DM (28 kg silage as fed) and 9.4 kg compound DM (10.9 kg cake as fed) will meet the cow's energy requirements.

LINEAR PROGRAMMING OF DAIRY COW RATIONS

Because of the additive nature of this ME system for dairy cows, linear programming using the ME values of foods is acceptable, subject to the application of total appetite constraints. Thus the ME values of foods define their replacement rates in dairy cattle rations, e.g. 1 kg barley DM (13.7 MJ/kg) will be replaced by 1.6 kg average hay DM (8.4 MJ/kg)

Such a replacement rate is markedly different from that given for the same foods by the starch equivalent system. This is due to the constant efficiency ($k_l$ = 0.62) with which food ME is used for lactation, compared with the widely varying efficiency with which food ME is used for fattening.

## Feeding the Dairy Cow

SIGNIFICANCE OF LIVEWEIGHT CHANGES

A typical 2 year old Friesian heifer after calving should weigh 450 kg, compared to a mature body weight by the 4th lactation of 600 kg. Thus growth to mature body size of about 40 kg per lactation must also be allowed for in feeding programmes.

At parturition the cow loses a total of 60-70 kg liveweight comprising a calf of 40-50 kg birthweight and the associated tissues or afterbirth. Subsequently during the early weeks of lactation it is difficult to prevent further liveweight loss (mostly from fat reserves), this loss contributing to the cow's energy supply for lactation. This initial loss of liveweight should be regained during the middle of the lactation and then further growth should be allowed for (up to the 4th lactation) in addition to the requirements of the growing calf.

Evidence has accumulated that the scale of liveweight loss in cows in early lactation is related to the incidence of acetonaemia, low SNF in milk, and non-specific infertility, as well as reducing peak yield and thus lactation performance. It is suggested that in early lactation liveweight loss should be kept below 30 kg, or 0.5 kg per day.

In terms of liveweight gains or losses the following lactation pattern is suggested as being both desirable and typical of well fed, high yielding cows.

**Table B**

*Desirable liveweight change pattern*

| Week number | Liveweight change, (kg/day) | Change during 10 weeks, (kg) | Net effect on liveweight, (kg) |
|---|---|---|---|
| 0–10 | − 0·5 | − 35 | − 35 |
| 10–20 | 0 | 0 | − 35 |
| 20–30 | + 0·5 | + 35 | 0 |
| 30–40 | + 0·5 | + 35 | + 35 |
| 40–52 | + 0·75 | + 63 | + 98 |

RATION FORMULATION FOR VARIOUS STAGES OF LACTATION

To show the consequence of this approach upon rations consider the following examples.

*Example 11*

A Friesian cow weighing 600 kg has a yield of 23 kg/day at 2 weeks. Only silage 9 MJ/kg DM and compound food 12.5 MJ/kg DM are available.

*First 10 weeks, early lactation*

*Calculation of peak yield*

Peak yield ($Y_p$) is related to yield at 2 weeks ($Y_2$) by the formula

$$Y_p = 1.1\ Y_2 \text{ kg/day} \tag{24}$$

$$\text{Thus} \quad Y_p = 1.1 \times 23 = 25 \textit{ kg/day}$$

Alternatively probable peak yield can be estimated from the anticipated lactation milk yield of the cow divided by 200 i.e.,

$$Y_p = \frac{\text{Lactation yield (kg)}}{200} \text{ kg/day} \tag{25}$$

In this example the anticipated lactation yield in 305 days is 5,000 kg milk. Expected peak milk yield is therefore

$$Y_p = \frac{5000}{200} = 25 \textit{ kg/day}$$

*Probable dry matter appetite in early lactation*

$$\begin{aligned} \text{From equation (22), DMI} &= 0.025\ W + 0.1\ Y - 2.5^* \\ &= 15 + 2.5 - 2.5 \\ &= 15 \textit{ kg DM/day} \end{aligned}$$

* *correction for early lactation*

Maximum liveweight loss allowable = 0.5 kg/day

ME allowance can now be calculated:

$$\begin{aligned} M_m &= 63 \text{ MJ (Table 1)} \\ M_p &= 25 \times 4.9 = 123 \text{ MJ (Table 2)} \\ M_g &= -(0.5 \times 28) = -14 \text{ MJ} \\ \textit{ME allowance} &= 63 + 123 - 14 = \textit{172 MJ day} \text{ (Table 4)} \\ M/D &= \frac{172}{15} = \textit{11.5 MJ/kg DM} \end{aligned}$$

Using equation (23)

$$FD = \frac{15\,(12.5 - 11.5)}{(12.5 - 9)} = \textit{4.3 kg DM forage}$$

$$CD = 15 - 4.3 = \textit{10.7 kg DM compound (12.6 kg as fed)}$$

Thus the forage is supplying $4.3 \times 9 = 39$ MJ, or two-thirds of the maintenance needs of the cow, whilst the compound is being fed at 0.5 kg/kg of milk, which amounts to *lead feeding* of 1.6 kg of compound food, equivalent to 3.6 kg of milk. Despite this lead feeding, the cow is losing 0.5 kg body weight daily.

*Weeks 10-20, mid lactation*

Peak milk yield of 25 kg will have been achieved and will begin to decline at about 2.5% each week. Liveweight loss should be brought to an end and dry matter appetite will be maximal.

Thus

$$M_m = 63 \text{ MJ}$$

$$M_p = 123 \text{ MJ reducing to 99 MJ for 20 kg milk (Table 2)}$$

$$M_g = 0$$

$$\textit{ME allowance} = 63 + 123 = \textit{186 MJ reducing to 162 MJ}$$

$$\textit{DMI} = 0.025\ W + 0.1\ Y = \textit{17.5 kg DM/day} \text{ (Table 6)}$$

$$M/D = \frac{186}{17.5} = \textit{10.6 MJ/kg DM}$$

$$FD = \textit{9.5 kg/day of forage DM}$$

$$CD = \textit{8.0 kg/day of compound DM}$$

The forage is now supplying 9.5 × 9 = 86 MJ of ME daily equivalent to maintenance and 4.7 kg of milk.

Using the liveweight change pattern suggested earlier, the results of similar calculations for the various stages of lactation of a cow are given below.

**Table C**

*Rations for various stages of lactation of typical Friesian cow*

| Week number | Milk yield (kg) | Livewt gain (kg) | DM intake (kg) | ME reqd (MJ) | M/D (MJ/kg) | Forage DM (kg) | Compound DM (kg) | Total DM supplied (kg) | Compound as fed (kg) | Compound per kg milk (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0–10 | 15–25 | − 0·5 | 15·0 | 172 | 11·5 | 4·3 | 10·7 | 15·0 | 12·2 | 0·49 |
| 10–20 | 25 | 0 | 17·5 | 186 | 10.6 | 9·5 | 8·0 | 17·5 | 9·1 | 0·36 |
| 20–30 | 20 | + 0·5 | 17·0 | 177 | 10·4 | 10·2 | 6·8 | 17·0 | 7·7 | 0·39 |
| 30–40 | 15 | + 0·5 | 16·5 | 152 | 9·2 | 10·0* | 5·0 | 15·0 | 5·7 | 0·38 |
| 40–50 | 10 | + 0·75 | 16·0 | 135 | 8·4 | 10·0* | 3·6 | 13·6 | 4·1 | 0·41 |

*Forage restricted to 10 kg DM/day voluntary intake as silage.

### FEEDING RATES FOR FEEDING ACCORDING TO YIELD

Whilst there is evidence that feeding according to yield in the strictest sense is not really necessary, it is still a widespread method of deciding food allocations for cows. Feeding rates which are in accordance with the ME allowances of cows, assuming standard dairy compound food has an ME of 11 MJ/kg as fed, are as follows:

| | |
|---|---|
| Friesian milk | 0.44 kg/kg milk |
| Ayrshire milk | 0.46 kg/kg milk |
| Channel Island milk | 0.54 kg/kg milk |

0.44 kg/kg milk is equivalent to 4.5 lb/gallon of milk.

ENERGY REQUIREMENTS OF GRAZING DAIRY COWS

Observations of cows at grass show that they are capable of gaining 1kg/day or more in spring, as well as milking heavily, and that if they are to calve down in satisfactory condition, they will need to gain between 0.5 and 0.75 kg/day during the grazing season. Since 1 kg of liveweight gain is equivalent to 34 MJ, the energy requirement for an average gain of 0.5 kg over a grazing season of 150 days would be 2,500 MJ, *equivalent to 250 kg of grass DM*.

This substantial additional energy requirement of grazing cows is usually overlooked when calculating pasture outputs.

It follows that the first consequence of shortage of grazing upon cows is a reduction in liveweight gain rather than milk yield. Supplementary foods offered whilst cows are at grass will first of all affect liveweight gain rather than milk yield. In the long term this may be a sound decision, because cows store surplus food energy and release it very efficiently.

## SUMMARY

### ME System for Dairy Cows

MAINTENANCE ALLOWANCES

$$M_m = 8.3 + 0.091\ W \qquad \text{(Table 1)}$$

(including activity allowance and a safety margin)

MILK PRODUCTION ALLOWANCES

Energy value of milk: $EV_l = 0.0386\ BF + 0.0205\ SNF - 0.236$ (MJ/kg)

Energy secreted as milk: $E_l = EV_l \times Y$ (MJ)

Efficiency of ME utilisation for lactation: $k_l = 0.62$

ME allowance for milk produced: $M_l = 1.69\ E_l$ (MJ) (Tables 2 and 3) (including safety margin)

*ME for average milk* (36 g/kg BF, 86 g/kg SNF) *4.9 MJ/kg*

*ME for SCM milk* (40 g/kg BF, 89 g/kg SNF) *5.3 MJ/kg*

ADJUSTMENTS TO ENERGY ALLOWANCES TO ALLOW FOR LIVEWEIGHT CHANGE IN LACTATING COWS

$$M_g = +\ 34\ MJ/kg\ gain$$

$$M_g = -\ 28\ MJ/kg\ loss$$

# SECTION III

## The use of the Metabolisable Energy System for growing and fattening cattle

The system provides a convenient method of predicting liveweight gain from a knowledge of ME intake and ME concentration of the ration. It is also possible to use it for the formulation of rations to give desired levels of performance.

### Prediction of Performance

It is convenient to consider the likely production from a given intake of ME for beef cattle in two separate stages—the energy allowance for maintenance and then the energy available for liveweight gain. To predict the expected liveweight gain from a given ration it is necessary to know the following:

(a) liveweight, W (kg)

(b) weights of individual foods given (kg)

(c) dry matter DM (g/kg) and metabolisable energy MEF (MJ/kg DM) contents of the foods

and to calculate:

(d) total ME supplied by the ration, MER (MJ)

(e) dry matter content of the ration, DMI (kg)

(f) energy concentration of the ration, M/D (MJ/kg)

(g) ME allowance for maintenance, $M_m$ (MJ)

(h) ME available for production, MEP (MJ)

(j) expected liveweight gain, LWG (kg/day)

CALCULATION OF THE TOTAL ME AND ENERGY CONCENTRATION OF THE RATION

The food dry matter and ME contributions are summed as shown in the following example:

*Example 12*

Prediction of expected liveweight gain of a 250 kg steer receiving the following daily ration:

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 4.1 kg hay | (870 g/kg DM and 9 MJ/kg DM) | 3.6 | 32.1 |
| 1.7 kg barley | (840 g/kg DM and 12.5 MJ/kg DM) | 1.4 | 17.9 |
| | | 5.0 | 50.0 |

*Total ME of ration, MER = 50 MJ/day*

$$\text{Hence the ration energy concentration } M/D = \frac{50}{5.0} = 10 \text{ MJ/kg}$$

### CALCULATION OF THE ME ALLOWANCE FOR MAINTENANCE

As indicated in Section I, the minimum net energy that must be available for maintenance is the fasting metabolism (FM) and may be calculated from the equation

$$FM = 5.67 + 0.061\ W \tag{4}$$

Since no activity increment is considered necessary for beef cattle kept indoors, this represents the net energy for maintenance ($E_m$).
Since the efficiency ($k_m$), with which ME is utilised for maintenance is 0.72, the ME requirement for maintenance, ($M_m$) is

$$\frac{FM}{0.72} = 1.39\ FM$$

Including a 0.05 safety margin the ME allowance for maintenance, ($M_m$) becomes

$$M_m = 8.3 + 0.091\ W \tag{20}$$

Values of $M_m$ for various liveweights are shown in Table 1.

**Table 1**

*Daily maintenance allowance of ME for beef cattle and dairy cows*

| Body weight (kg) | MJ/head |
|---|---|
| 100 | 17 |
| 150 | 22 |
| 200 | 27 |
| 250 | 31 |
| 300 | 36 |
| 350 | 40 |
| 400 | 45 |
| 450 | 49 |
| 500 | 54 |
| 550 | 59 |
| 600 | 63 |

(including safety margin)
Based on $M_m = 8{\cdot}3 + 0{\cdot}091\ W$

(Note: The values are the same as those for dairy cattle but do not include an activity allowance).

Reference to Table 1 shows that for a liveweight of 250 kg, 31 MJ of ME will be needed for maintenance ($M_m$).

### CALCULATION OF THE ME AVAILABLE FOR PRODUCTION

The ME available for liveweight gain (MEP) can be found by deducting the ME allowance for maintenance ($M_m$) from the total ME of the ration (MER):

$$MEP = MER - M_m \tag{26}$$

Thus in *Example 12*,

ME available for production *MEP* $= 50 - 31$
$= $ *19 MJ* @ M/D 10 MJ/kg

CALCULATION OF PREDICTED LIVEWEIGHT GAIN

The efficiency ($k_g$) with which MEP will be utilised for gain, as indicated in Section I, depends on the energy concentration, (M/D) of the ration

$$k_g = 0.0435\ M/D \tag{8}$$

Allowing for a 0.05 safety margin, the net energy that will be used for growth, ($E_g$) can be calculated as follows:

$$E_g = \frac{MEP \times 0.0435\ M/D}{1.05} \tag{27}$$

In *Example 12* above, MEP = 19 MJ and M/D = 10 MJ/kg

$$\text{and } E_g = \frac{19 \times 0.0435 \times 10}{1.05}\ \text{MJ}$$

$$= 7{\cdot}9\ MJ$$

Values of $E_g$ for various combinations of MEP and M/D are shown in Table 8.

**Table 8**

*MJ net energy stored $E_g$, from ME available for production MEP, at energy concentration M/D*

| MEP (MJ) | Energy concentration M/D, (MJ/kg DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 5 | 1·4 | 1·7 | 1·9 | 2·1 | 2·3 | 2·5 | 2·7 | 2·9 |
| 10 | 2·9 | 3·3 | 3·7 | 4·1 | 4·6 | 5·0 | 5·4 | 5·8 |
| 15 | 4·3 | 5·0 | 5·6 | 6·2 | 6·8 | 7·5 | 8·1 | 8·7 |
| 20 | 5·8 | 6·6 | 7·5 | 8·3 | 9·1 | 9·9 | 10·8 | 11·6 |
| 25 | 7·2 | 8·3 | 9·3 | 10·4 | 11·4 | 12·4 | 13·5 | 14·5 |
| 30 | 8·7 | 9·9 | 11·2 | 12·4 | 13·7 | 14·9 | 16·1 | 17·4 |
| 35 | 10·1 | 11·6 | 13·0 | 14·5 | 15·9 | 17·4 | 18·8 | 20·3 |
| 40 | 11·6 | 13·2 | 14·9 | 16·6 | 18·2 | 19·9 | 21·5 | 23·2 |
| 45 | 13·0 | 14·9 | 16·8 | 18·6 | 20·5 | 22·4 | 24·2 | 26·1 |
| 50 | 14·5 | 16·6 | 18·6 | 20·7 | 22·8 | 24·8 | 26·9 | 29·0 |
| 55 | 15·9 | 18·2 | 20·5 | 22·8 | 25·0 | 27·3 | 29·6 | 31·9 |
| 60 | 17·4 | 19·9 | 22·4 | 24·8 | 27·3 | 29·8 | 32·3 | 34·8 |
| 65 | 18·8 | 21·5 | 24·2 | 26·9 | 29·6 | 32·3 | 35·0 | 37·7 |
| 70 | 20·3 | 23·2 | 26·1 | 29·0 | 31·9 | 34·8 | 37·7 | 40·6 |
| 75 | 21·7 | 24·8 | 27·9 | 31·1 | 34·2 | 37·3 | 40·4 | 43·5 |
| 80 | 23·2 | 26·5 | 29·8 | 33·1 | 36·4 | 39·8 | 43·1 | 46·4 |

The liveweight gain (LWG) that can be achieved from the stored energy ($E_g$) as shown in Section I, is dependent upon the energy value of the gain ($EV_g$), which in turn is related to the liveweight of the animal (W) and the net energy stored as gain ($E_g$). These relationships can be expressed as equation (9) discussed in Section I.

$$\text{LWG} = \frac{E_g}{(6.28 + 0.3\ E_g + 0.0188\ W)} \tag{9}$$

In *Example 12* the liveweight gain possible for a 250 kg steer from a net energy ($E_g$) of 7.9 MJ is 0.60 kg per day.

The liveweight gains possible from various levels of energy stored, ($E_g$) for different liveweights (W) are given in Table 9.

**Table 9**

*Liveweight gain in kg/day for MJ net energy stored $E_g$, in animals of liveweight W*

| $E_g$ (MJ) | Liveweight W (kg) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 |
| 2 | 0·23 | 0·21 | 0·19 | 0·17 | 0·16 | 0·15 | 0·14 | 0·13 | 0·12 | 0·12 | 0·11 |
| 4 | 0·43 | 0·39 | 0·36 | 0·33 | 0·30 | 0·28 | 0·27 | 0·25 | 0·24 | 0·22 | 0·21 |
| 6 | 0·60 | 0·55 | 0·51 | 0·47 | 0·44 | 0·41 | 0·38 | 0·36 | 0·34 | 0·33 | 0·31 |
| 8 | 0·76 | 0·70 | 0·64 | 0·60 | 0·56 | 0·52 | 0·49 | 0·47 | 0·44 | 0·42 | 0·40 |
| 10 | 0·90 | 0·83 | 0·77 | 0·72 | 0·67 | 0·63 | 0·60 | 0·56 | 0·54 | 0·51 | 0·49 |
| 12 | 1·02 | 0·94 | 0·88 | 0·82 | 0·77 | 0·73 | 0·69 | 0·65 | 0·62 | 0·59 | 0·57 |
| 14 | | 1·05 | 0·98 | 0·92 | 0·87 | 0·82 | 0·78 | 0·74 | 0·70 | 0·67 | 0·64 |
| 16 | | | 1·08 | 1·01 | 0·96 | 0·91 | 0·86 | 0·82 | 0·78 | 0·75 | 0·72 |
| 18 | | | 1·17 | 1·10 | 1·04 | 0·99 | 0·94 | 0·89 | 0·85 | 0·82 | 0·78 |
| 20 | | | | 1·18 | 1·12 | 1·06 | 1·01 | 0·96 | 0·92 | 0·88 | 0·85 |
| 22 | | | | 1·25 | 1·19 | 1·13 | 1·08 | 1·03 | 0·99 | 0·95 | 0·91 |
| 24 | | | | | 1·26 | 1·20 | 1·14 | 1·09 | 1·05 | 1·01 | 0·97 |
| 26 | | | | | 1·32 | 1·26 | 1·20 | 1·15 | 1·11 | 1·06 | 1·03 |
| 28 | | | | | | 1·32 | 1·26 | 1·21 | 1·16 | 1·12 | 1·08 |
| 30 | | | | | | 1·37 | 1·32 | 1·26 | 1·22 | 1·17 | 1·13 |
| 35 | | | | | | | 1·44 | 1·39 | 1·34 | 1·29 | 1·25 |
| 40 | | | | | | | | 1·50 | 1·45 | 1·40 | 1·35 |
| 45 | | | | | | | | | 1·54 | 1·49 | 1·45 |
| 50 | | | | | | | | | | 1·58 | 1·54 |

$$\text{Based on LWG} = \frac{E_g}{(6{\cdot}28 + 0{\cdot}3\ E_g + 0{\cdot}0188\ W)}$$

Below are some example calculations for predicting the liveweight gain from given rations, beginning with the example outlined in the text:

*Example 12*

Prediction of the liveweight gain of a steer weighing 250 kg receiving the following daily ration:

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 4.1 kg hay | (870 g/kg DM and 9 MJ/kg DM) | 3.6 | 32.1 |
| 1.7 kg barley | (840 g/kg DM and 12.5 MJ/kg DM) | 1.4 | 17.9 |
| | | 5.0 | 50.0 |

$$\text{M/D} = \frac{50}{5\cdot0} = 10 \text{ MJ/kg}$$

$M_m$ = 31 MJ (Table 1)
MEP = 50 − 31 = 19 MJ @ M/D 10 MJ/kg
$E_g$ = 8 MJ (Table 8)
*LWG* = *0.6 kg* (Table 9)

The ration supplies 50 MJ at M/D 10 MJ/kg DM and will provide for maintenance and 0.6 kg liveweight gain per day.

*Example 13*

Calculation of the predicted liveweight gain of a 235 kg steer fed a ration of

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 9.5 kg silage | (217 g/kg DM and 8.8 MJ/kg DM) | 2.06 | 18.1 |
| 7.5 kg potatoes | (270 g/kg DM and 11.2 MJ/kg DM) | 2.03 | 22.7 |
| 2.5 kg barley | (870 g/kg DM and 12.5 MJ/kg DM) | 2.18 | 27.2 |
| | | 6.27 | 68.0 |

hence $$\text{M/D} = \frac{68.0}{6.27} = 10.85 \text{ MJ/kg}$$

$M_m$ = 30 MJ (derived from Table 1)
MEF = 68.0 − 30 = 38 MJ @ 10.85 MJ/kg
$E_g$ = 17.1 (Table 8)
*LWG* = *1.08* (Table 9)

The ration supplies 68 MJ at M/D 10.85 MJ/kg DM and will provide for maintenance and 1.1 kg liveweight gain per day.

## CALCULATION OF METABOLISABLE ENERGY ALLOWANCES FOR GROWING AND FATTENING CATTLE

It is necessary to know the following:

(a) animal's liveweight, W, (kg)
(b) desired rate of daily liveweight gain, LWG (kg/day)
(c) energy concentration of the ration, M/D (MJ/kg)

and to calculate:

(d) ME maintenance allowance, $M_m$, (MJ)
(e) energy stored as gain, $E_g$ (MJ)
(f) ME allowance for body gain, $M_g$ (MJ)
(g) total ME allowance (MJ/day)

$$\text{Maintenance allowance, } M_m = 8.3 + 0.091 \text{ W} \tag{20}$$

$$\text{Energy stored, } E_g = \frac{\text{LWG } (6.28 + 0.0188 \text{ W})}{(1 - 0.30 \text{ LWG})} \tag{7}$$

**Table 10**

*Daily ME allowances for growing and fattening cattle (MJ/head)*

| Liveweight (kg) | Ration M/D (MJ/kg) | Rate of gain (kg/day) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 0·25 | 0·50 | 0·75 | 1·00 | 1·25 | 1·50 |
| 100 | 8 | 17 | 24 | | | | | |
| | 10 | 17 | 22 | 29 | | | | |
| | 12 | 17 | 21 | 27 | 33 | | | |
| | 14 | 17 | 21 | 25 | 31 | 37 | | |
| 150 | 8 | 22 | 29 | | | | | |
| | 10 | 22 | 28 | 35 | | | | |
| | 12 | 22 | 27 | 33 | 40 | 48 | | |
| | 14 | 22 | 26 | 31 | 37 | 44 | 53 | |
| 200 | 8 | 27 | 35 | | | | | |
| | 10 | 27 | 34 | 41 | 51 | | | |
| | 12 | 27 | 33 | 39 | 47 | 56 | | |
| | 14 | 27 | 32 | 37 | 45 | 52 | 62 | 74 |
| 250 | 8 | 31 | 40 | 51 | | | | |
| | 10 | 31 | 38 | 47 | 57 | | | |
| | 12 | 31 | 37 | 44 | 52 | 63 | 75 | |
| | 14 | 31 | 36 | 42 | 49 | 58 | 69 | 83 |
| 300 | 8 | 36 | 46 | 57 | | | | |
| | 10 | 36 | 44 | 53 | 64 | | | |
| | 12 | 36 | 43 | 50 | 59 | 70 | 84 | |
| | 14 | 36 | 42 | 48 | 56 | 65 | 77 | 92 |
| 350 | 8 | 40 | 51 | 63 | | | | |
| | 10 | 40 | 48 | 58 | 70 | 84 | | |
| | 12 | 40 | 47 | 55 | 65 | 77 | 92 | |
| | 14 | 40 | 46 | 53 | 62 | 72 | 84 | 101 |
| 400 | 8 | 45 | 56 | 70 | | | | |
| | 10 | 45 | 54 | 65 | 77 | 93 | | |
| | 12 | 45 | 53 | 61 | 72 | 85 | 101 | |
| | 14 | 45 | 51 | 59 | 68 | 79 | 93 | 110 |
| 450 | 8 | 49 | 61 | 75 | | | | |
| | 10 | 49 | 59 | 70 | 83 | | | |
| | 12 | 49 | 57 | 67 | 78 | 91 | 108 | |
| | 14 | 49 | 56 | 64 | 74 | 85 | 100 | 118 |
| 500 | 8 | 54 | 67 | 82 | | | | |
| | 10 | 54 | 64 | 76 | 91 | | | |
| | 12 | 54 | 63 | 73 | 85 | 99 | 117 | |
| | 14 | 54 | 61 | 70 | 80 | 93 | 108 | 128 |
| 550 | 8 | 59 | 73 | 89 | | | | |
| | 10 | 59 | 70 | 83 | 98 | | | |
| | 12 | 59 | 68 | 79 | 91 | 107 | 126 | |
| | 14 | 59 | 67 | 76 | 87 | 100 | 116 | 137 |
| 600 | 8 | 63 | 77 | 94 | | | | |
| | 10 | 63 | 75 | 88 | 104 | | | |
| | 12 | 63 | 73 | 84 | 97 | 114 | 134 | |
| | 14 | 63 | 71 | 81 | 92 | 106 | 124 | 146 |

$$\text{ME for body gain } M_g = \frac{E_g}{k_g} \text{ then}$$

$$M_g = \frac{24.1\ E_g}{M/D} \tag{27}$$

which is a rearranged version of equation (27).

$$\textit{Total ME allowance (MJ/day)} = M_m + M_g$$

Calculated ME allowances for growing and fattening beef cattle from 100 to 600 kg liveweight and gaining up to 1.5 kg/day are given in Table 10.

Inspection of Table 10 will show that the ME allowances for beef cattle vary according to the energy concentration of the ration fed (M/D), when a particular rate of gain is required. The ME of poorer foods such as hay (M/D = 8) is used less efficiently for gain than cereals such as barley (M/D = 14). This is a consequence of the effect of M/D on $k_g$ as given in equation (8).

This interaction between the energy concentration of the ration and the ME allowance leads to some difficulty in ration formulation for beef cattle, but several methods can be used to solve this problem.

**Formulation of a Ration to give a Desired Level of Production**

In order to be able to formulate the ration to allow a desired rate of gain it is necessary to know the following:

(a) liveweight of the animal, W (kg)
(b) liveweight gain required, LWG (kg/day)
(c) ME content of the available foods, MEF (MJ/kg)
(d) dry matter content of the available foods, DM (g/kg)
(e) èstimated dry matter appetite of the animal (kg/day)

and to calculate:

(f) ME allowance for maintenance, $M_m$ (MJ)
(g) net energy allowance for production, $E_g$ (MJ)
(h) range of ME required for production, $M_g$ (MJ)

The value of energy stored ($E_g$) for a particular rate of gain will enable the ME required for production ($M_g$), to be calculated for the range of energy concentrations (M/D) of the foods available.

*Example 14*

Ration formulation for a steer of 250 kg liveweight required to gain 0.8 kg/day.

The foods available are hay and beef compound nuts:

| | | | |
|---|---|---|---|
| Hay | 850 g/kg DM, 8.0 MJ/kg DM | | |
| Beef compound | 880 g/kg DM, 12.5 MJ/kg DM | | |
| Dry matter appetite, | | DMI | = 6.6 kg/day |
| Maintenance ME allowance, | | $M_m$ | = 31 MJ (Table 1) |
| Net energy allowance for production, | | $E_g$ | = 11.6 MJ (Table 9) |

The range of M/D values to be considered for predicting the ME for production is from 8.0 MJ/kg DM for the hay to 12.5 MJ/kg DM for the compound. Inspection of Table 8 shows that for a value for $E_g$ of 12 MJ, values for $M_g$ will be between 24 to 36 MJ for the energy concentrations available in the foods.

Since $M_m$ = 31 MJ, the total ME allowance will be in the range 55-67 MJ/day.

*1st Attempted Solution*

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 6 kg hay, (850 g/kg DM, 8 MJ/kg DM) | 5.1 | 40.8 |
| 1.5 kg nuts, (880 g/kg DM, 12.5 MJ/kg DM) | 1.3 | 16.5 |
| | 6.4 | 57.3 |

M/D = 8.95 MJ/kg DM
MEP = 57.3 − 31 = 26.3 MJ
$E_g$ = 26.3 × 0.0414 × 8.95 MJ
= 9.7 MJ compared with 11.6 MJ required

*2nd Attempted Solution*

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 5 kg hay, (850 g/kg DM, 8.0 MJ/kg DM) | 4.25 | 34.0 |
| 2.5 kg nuts, (880 g/kg DM, 12.5 MJ/kg DM) | 2.20 | 27.5 |
| | 6.45 | 61.5 |

M/D = 9.5 MJ/kg DM
MEP = 61.5 − 31 = 30.5
$E_g$ = 12.0 MJ compared with 11.6 MJ required

This may be regarded as a close enough approximation for practical purposes, but is obviously not the exact solution which is

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 5.5 kg hay, (850 g/kg DM, 8 MJ/kg DM) | 4.68 | 37.4 |
| 2.15 kg nuts, (880 g/kg DM, 12.5 MJ/kg DM) | 1.89 | 23.6 |
| | 6.57 | 61.0 |

M/D = 9.3 MJ/kgDM
MEP = 61 − 31 = 30 MJ
$E_g$ = *11.6 MJ equal to a gain of 0.8 kg/day*

Thus a ration consisting of 5.5 kg hay DM and 2.15 kg compound DM will supply 61 MJ of ME at a ration concentration of 9.3 MJ/kg and will provide 0.8 kg gain per day in a 250 kg steer

### A RAPID METHOD OF RATION FORMULATION

The foregoing iterative method of calculation is slow and laborious, and a more satisfactory procedure will now be outlined, which gives the exact

answer directly, provided that dry matter appetite of the animal can be specified.

*Theory of the method*

By definition, ME intake = Dry matter intake × M/D

$$\text{or ME} = \text{DMI} \times \text{M/D}$$

and ideally ration ME should be equal to $M_m + M_g$

$$M_m = 8.3 + 0.091\ W \quad (20)$$

$$M_g = \frac{24.1\ E_g}{M/D} \quad (27)$$

$$\text{therefore DMI} \times M/D = M_m + \frac{24.1\ E_g}{M/D} \quad (28)$$

All the terms in equation (28) are known, being directly related either to liveweight (W) (Table 1), or to liveweight gain (Table 9). Roy's (1959)[1] values for dry matter intakes may be used.

The equation is therefore a quadratic of the form

$ax^2 + bx + c = 0$ where $x = M/D$, as follows:

$$\text{DMI} \times (M/D)^2 - M_m \times M/D - 24.1\ E_g = 0 \quad (29)$$

and the solution using the formula $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$\text{is given by} \quad M/D = \frac{M_m + \sqrt{M_m^2 + (96.6\ \text{DMI} \times E_g)}}{2\text{DMI}} \quad (30)$$

From equation (30) can be calculated the exact energy concentration (M/D) which satisfies both the animal's dry matter appetite and its need for ME for maintenance and gain. Calculated values are given in Table 11.

The use of this concept of minimum M/D values for rations is the key to simple ration formulation in the ME system. If the ration consists of only 2 components, forage and supplement, the amounts of two foods required may be calculated as for dairy cattle using equation (23):

$$\text{FD, forage dry matter intake} = \frac{\text{DMI (MC} - \text{M/D)}}{(\text{MC} - \text{MF})}\ \text{kg/day} \quad (23)$$

and CD, cereal/compound dry matter = DMI − FD kg/day

where MF is the ME of forage DM

MC is the ME of cereals or compound DM

M/D is the value in Table 11 required

and DMI is the dry matter appetite given in Table 11.

[1] Proceedings of the Brighton Conference, 1959

**Table 11**

*Minimum metabolisable energy concentration of beef cattle diets, M/D (MJ/kg DM)*

| Gain (kg/day) | Liveweight W (kg) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 |
| 0 | (5·8) | (5·2) | (4·8) | (4·7) | (4·6) | (4·7) | (4·8) | (4·9) | (5·1) | (5·3) | (5·4) |
| 0·1 | (6·8) | (6·0) | (5·5) | (5·4) | (5·3) | (5·4) | (5·5) | (5·5) | (5·7) | (5·9) | (6·0) |
| 0·2 | 7·6 | (6·8) | (6·2) | (6·1) | (5·9) | (6·0) | (6·0) | (6·1) | (6·2) | (6·4) | (6·6) |
| 0·3 | 8·4 | 7·5 | (6·9) | (6·7) | (6·5) | (6·5) | (6·6) | (6·6) | (6·8) | 7·0 | 7·1 |
| 0·4 | 9·1 | 8·1 | 7·5 | 7·2 | 7·0 | 7·0 | 7·1 | 7·1 | 7·3 | 7·5 | 7·6 |
| 0·5 | 9·8 | 8·7 | 8·0 | 7·8 | 7·5 | 7·5 | 7·6 | 7·6 | 7·7 | 7·9 | 8·1 |
| 0·6 | 10·5 | 9·3 | 8·5 | 8·3 | 8·1 | 8·0 | 8·0 | 8·1 | 8·2 | 8·4 | 8·5 |
| 0·7 | 11·1 | 9·8 | 9·1 | 8·8 | 8·5 | 8·5 | 8·5 | 8·5 | 8·7 | 8·8 | 9·0 |
| 0·8 | 11·8 | 10·4 | 9·6 | 9·3 | 9·0 | 9·0 | 9·0 | 9·0 | 9·1 | 9·3 | 9·5 |
| 0·9 | 12·5 | 11·0 | 10·1 | 9·8 | 9·5 | 9·4 | 9·5 | 9·5 | 9·6 | 9·8 | 9·9 |
| 1·0 | 13·1 | 11·6 | 10·7 | 10·3 | 10·0 | 9·9 | 9·9 | 9·9 | 10·1 | 10·2 | 10·4 |
| 1·1 | 13·8 | 12·1 | 11·2 | 10·8 | 10·5 | 10·4 | 10·4 | 10·4 | 10·6 | 10·7 | 10·9 |
| 1·2 | 14·5 | 12·8 | 11·8 | 11·3 | 11·0 | 10·9 | 10·9 | 10·9 | 11·1 | 11·2 | 11·4 |
| 1·3 | | 13·4 | 12·4 | 11·9 | 11·6 | 11·5 | 11·4 | 11·4 | 11·6 | 11·7 | 11·9 |
| 1·4 | | 14·0 | 13·0 | 12·5 | 12·1 | 12·0 | 12·0 | 12·0 | 12·1 | 12·3 | 12·5 |
| 1·5 | | | 13·6 | 13·1 | 12·7 | 12·6 | 12·5 | 12·5 | 12·7 | 12·9 | 13·0 |
| DMI (kg) | 2·94 | 4·26 | 5·48 | 6·60 | 7·62 | 8·54 | 9·36 | 10·08 | 10·70 | 11·22 | 11·65 |

( ) indicates values are theoretical only, appetite limits on poor quality forages make M/D infeasible.

*Example 15*

Formulation of a ration for a 300 kg steer to gain 1.0 kg/day

From Table 11, minimum M/D = 10.0 MJ/kg and DMI = 7.62 kg/day

If forage ME, MF = 9 MJ/kg DM

compound ME, MC = 12 MJ/kg DM

$$\text{then } FD = \frac{7.62\,(12 - 10)}{(12 - 9)} = 5.08 \text{ kg/day}$$

$$\text{and } CD = 7.62 - 5.08 = 2.54 \text{ kg/day}$$

Hence the desired ration is 5.08 kg forage DM and 2.54 kg compound DM.

The ration formulation equation (23), for calculating weight of forage dry matter required for a given energy concentration (M/D), will only handle a two component ration. A little ingenuity, however, can be used to handle more foods, if they can be grouped and proportioned so that the mixture can be given an ME value, e.g.,

$$\left.\begin{array}{ll}\text{given hay @} & 8 \text{ MJ/kg DM} \\ \text{silage} & \text{@ } 10 \text{ MJ/kg DM}\end{array}\right\} \text{ fed in equal proportions}$$

the mix would have an ME value of 9 MJ which can be inserted as MF in equation (23).

Normally, however, if a variety of foods is to be included in a ration and economic considerations taken into account, the use of the linear programming technique is desirable.

### LINEAR PROGRAMMING OF RATIONS FOR BEEF ANIMALS

It should by now be apparent that the ME value of a food does not accurately represent its contribution to animal production, since the efficiency of utilisation of the ME for liveweight gain ($k_g$), is influenced by the energy concentration (M/D), and therefore by the other foods in the ration.

Diets for pigs and poultry are commonly formulated to specified energy concentrations, whilst complete diets for dairy cattle would be formulated to a given amount of ME (MJ). With beef cattle, both approaches must be used together. The ration must be defined by both terms, total ME and energy concentration (M/D), otherwise linear programming using ME alone as the energy constraint is unsound. The right hand side of the matrix must have values for both total ME and the chosen energy concentration (M/D). Alternatively a statement of dry matter intake (DMI) required can be used instead of M/D, since M/D = ME/DMI.

The break-even prices and substitution rates which can be calculated for rations for low rates of gain will differ substantially from those found when rations for high rates of gain are formulated.

An alternative approach is to use the variable net energy system now to be described.

## Variable Net Energy System for Ration Formulation

This system is based on principles put forward by MacHardy (1965)[1], and worked out in detail by Harkins, Edwards and McDonald (1974)[2]. It calculates the net energy for each food at the level of animal production under study, thus making the system additive, and ideal for use in linear programme work. Replacement rates can be calculated for any situation, and it is of great value in desk formulation of multi feed rations without recourse either to linear programming or the use of equation (30) described earlier.

The system states allowances in net energy and is based on two concepts, Animal Production Level (APL), and Net Energy for maintenance and production ($NE_{mp}$), which were discussed at the end of Section I. For any given animal production level a food has a net energy dependent upon its metabolisable energy concentration. Tables may be constructed which allow the net energy ($NE_{mp}$) values to be obtained if the production situation and metabolisable energy values (MEF) of the foods are known.

### ANIMAL PRODUCTION LEVEL

This is defined as the ratio between the total net energy requirement and the net energy required for maintenance ($E_m$):

$$\text{Animal Production Level, APL} = \frac{E_m + E_p}{E_m} = 1 + \frac{E_p}{E_m} \qquad (19)$$

$$\text{given that } E_m = 5.67 + 0.061\ W \qquad (4)$$

[1]Abst. 9th Int Cong. Anim. Prod., p25. [2]Anim. Prod. **19**, 141, 1974

$$\text{and } E_p = \frac{\text{LWG } (6.28 + 0.0188 \text{ W})}{(1 - 0.30 \text{ LWG})} \tag{7}$$

then for this energy system,

$$\text{APL} = 1 + \left[ \frac{\text{LWG } (6.28 + 0.0188 \text{ W})}{(1 - 0.3 \text{ LWG}) (5.67 + 0.061 \text{ W})} \right] \tag{31}$$

Values for APL at different levels of liveweight (W), and liveweight gain (LWG), are stated in Table 12. At the maintenance level, when LWG = 0, APL = 1.

**Table 12**

*Animal production level*

| Liveweight W, (kg) | Liveweight gain LWG, (kg/day) | | | | | |
|---|---|---|---|---|---|---|
| | 0·25 | 0·50 | 0·75 | 1·00 | 1·25 | 1·50 |
| 100 | 1·19 | 1·40 | 1·66 | 1·98 | | |
| 150 | 1·16 | 1·36 | 1·59 | 1·87 | | |
| 200 | 1·15 | 1·33 | 1·54 | 1·79 | 2·11 | |
| 250 | 1·14 | 1·30 | 1·50 | 1·74 | 2·03 | |
| 300 | 1·13 | 1·29 | 1·47 | 1·70 | 1·97 | 2·33 |
| 350 | 1·13 | 1·27 | 1·45 | 1·67 | 1·93 | 2·27 |
| 400 | 1·12 | 1·26 | 1·43 | 1·64 | 1·90 | 2·22 |
| 450 | 1·12 | 1·26 | 1·42 | 1·62 | 1·87 | 2·18 |
| 500 | 1·11 | 1·25 | 1·41 | 1·60 | 1·84 | 2·15 |
| 550 | 1·11 | 1·24 | 1·40 | 1·59 | 1·83 | 2·13 |
| 600 | 1·11 | 1·24 | 1·39 | 1·58 | 1·81 | 2·13 |

$$\text{Based on APL} = 1 + \left[ \frac{\text{LWG } (6{\cdot}28 + 0{\cdot}0188\text{W})}{(1 - 0{\cdot}3 \text{ LWG}) (5{\cdot}67 + 0{\cdot}061 \text{ W})} \right]$$

### NET ENERGY FOR MAINTENANCE AND PRODUCTION

In the ME system for beef cattle which has been described the efficiency of utilisation of ME for maintenance ($k_m$) is fixed at 0.72, and the efficiency for fattening ($k_g$) is dependent on the ration energy concentration (M/D).

$$k_g = 0.0435 \text{ M/D} \tag{8}$$

Overall efficiency of ME use for maintenance and production ($k_{mp}$) is therefore variable, depending upon the proportions of ME used for maintenance and fattening. It may be defined as the ratio of net energy requirement for maintenance and production, to the total metabolisable energy requirement ($M_{mp}$):

$$k_{mp} = \frac{E_m + E_p}{M_{mp}} \tag{18}$$

$$\text{and } M_{mp} = M_m + M_p$$

$$\text{Hence } k_{mp} = \frac{E_m + E_p}{M_m + M_p} \tag{32}$$

Metabolisable energy required for maintenance, $M_m = \dfrac{E_m}{0.72} = 1.39\ E_m$

given that $APL = \dfrac{E_m + E_p}{E_m}$ then $E_p = E_m\ (APL - 1)$

Metabolisable energy required for production, $M_p = \dfrac{E_p}{0.0435\ M/D}$

$$= \frac{E_m\ (APL - 1)}{0.0435\ M/D}$$

Substituting for $E_p$, $M_m$ and $M_p$ in terms of either $E_m$, M/D or APL in equation (32) the following expression is obtained:

$$k_{mp} = \frac{M/D \times APL}{1.39\ M/D + 23\ (APL - 1)} \tag{33}$$

Thus the overall efficiency of ME use ($k_{mp}$) can be calculated for any given animal production level and energy concentration of the ration, as may be seen in the following table:

**Table D**

*Overall efficiency of ME utilisation, $k_{mp}$*

| APL | Ration energy concentration, M/D (MJ/kg DM) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1·00 | 0·72 | 0·72 | 0·72 | 0·72 | 0·72 | 0·72 | 0·72 |
| 1·25 | 0·59 | 0·62 | 0·64 | 0·65 | 0·67 | 0·68 | 0·69 |
| 1·50 | 0·53 | 0·56 | 0·59 | 0·62 | 0·64 | 0·66 | 0·68 |
| 1·75 | 0·49 | 0·53 | 0·56 | 0·59 | 0·62 | 0·64 | 0·67 |
| 2·00 | 0·47 | 0·51 | 0·54 | 0·58 | 0·61 | 0·63 | 0·66 |
| 2·25 | 0·45 | 0·49 | 0·53 | 0·56 | 0·59 | 0·62 | 0·65 |

The net energy for maintenance and production, ($NE_{mp}$) of either a ration or a food can be obtained by multiplying the ME concentration in the dry matter, (M/D or MEF) by $k_{mp}$, giving

$$NE_{mp} = \frac{(MEF)^2 \times APL}{1.39\ MEF + 23\ (APL - 1)}\ (MJ/kg\ DM) \tag{34}$$

The net energy values calculated using this equation are stated in Table 13.

Any production situation may be defined in terms of APL (Table 12), and $NE_{mp}$ values found by reference to Table 13.

**Table 13**

*Net energy values for maintenance and production, $NE_{mp}$ (MJ/kg DM)*

| APL | ME of food, MEF (MJ/kg DM) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1·00 | 5·8 | 6·5 | 7·2 | 7·9 | 8·6 | 9·4 | 10·1 |
| 1·10 | 5·2 | 6·0 | 6·8 | 7·6 | 8·3 | 9·1 | 9·9 |
| 1·15 | 5·1 | 5·8 | 6·6 | 7·4 | 8·2 | 9·0 | 9·8 |
| 1·20 | 4·9 | 5·7 | 6·5 | 7·3 | 8·1 | 8·9 | 9·8 |
| 1·25 | 4·7 | 5·5 | 6·4 | 7·2 | 8·0 | 8·9 | 9·7 |
| 1·30 | 4·6 | 5·4 | 6·3 | 7·1 | 7·9 | 8·8 | 9·7 |
| 1·35 | 4·5 | 5·3 | 6·2 | 7·0 | 7·8 | 8·7 | 9·6 |
| 1·40 | 4·4 | 5·2 | 6·1 | 6·9 | 7·8 | 8·7 | 9·6 |
| 1·45 | 4·3 | 5·1 | 6·0 | 6·8 | 7·7 | 8·6 | 9·5 |
| 1·50 | 4·2 | 5·1 | 5·9 | 6·8 | 7·7 | 8·6 | 9·5 |
| 1·55 | 4·2 | 5·0 | 5·8 | 6·7 | 7·6 | 8·5 | 9·5 |
| 1·65 | 4·1 | 4·9 | 5·7 | 6·6 | 7·5 | 8·4 | 9·4 |
| 1·75 | 3·9 | 4·8 | 5·6 | 6·5 | 7·4 | 8·4 | 9·3 |
| 2·00 | 3·8 | 4·6 | 5·4 | 6·3 | 7·3 | 8·2 | 9·2 |
| 2·25 | 3·6 | 4·4 | 5·3 | 6·2 | 7·1 | 8·1 | 9·1 |

Based on $NE_{mp} = \dfrac{(MEF)^2 \times APL}{1{\cdot}39\ MEF + 23\ (APL - 1)}$

NET ENERGY ALLOWANCES FOR BEEF CATTLE

The formulation of rations using the $NE_{mp}$ values of foods requires net energy allowances calculated in the same unit. These can be obtained by using equations for $E_m$ and $E_p$ already referred to:

$$E_m = 5.67 + 0.061\ W \quad (4)$$

$$\text{and } E_p = \frac{LWG\ (6.28 + 0.0188\ W)}{(1 - 0.3\ LWG)} \quad (7)$$

These values must be increased by the usual 0.05 safety margin as has been done with the other systems. Total net energy allowances for maintenance and gain are given in Table 14.

USE OF THE VARIABLE NET ENERGY SYSTEM FOR RATION FORMULATION

Within dry matter appetite limits, rations for beef animals can be constructed in an additive manner by using the appropriate $NE_{mp}$ values for the desired animal production level. In order to do this, it is necessary to know the following:

(a) animal's liveweight, W (kg)

(b) required rate of liveweight gain, LWG (kg/day)

(c) expected dry matter intake, DMI (kg/day)

(d) foods dry matter content, DM (g/kg)
and ME content, MEF (MJ/kg DM)

and to calculate

(e) animal production level, APL
(f) net energy allowance for maintenance and gain (MJ/day)
(g) appropriate $NE_{mp}$ values for each food (MJ/kg)

and to formulate a ration which meets the values in (f) and (c)

**Table 14**

*Net energy allowances (MJ/day) for maintenance and liveweight gain in growing and fattening animals*

| Gain (kg) | Liveweight, W (kg) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 |
| 0 | 12·4 | 15·6 | 18·8 | 22·0 | 25·2 | 28·4 | 31·6 | 34·8 | 38·0 | 41·2 | 44·4 |
| 0·1 | 13·3 | 16·6 | 19·9 | 23·2 | 26·5 | 29·8 | 33·1 | 36·4 | 39·7 | 43·0 | 46·3 |
| 0·2 | 14·2 | 17·6 | 21·0 | 24·5 | 27·9 | 31·3 | 34·7 | 38·1 | 41·5 | 44·9 | 48·3 |
| 0·3 | 15·2 | 18·8 | 22·3 | 25·8 | 29·3 | 32·9 | 36·4 | 39·9 | 43·4 | 47·0 | 50·5 |
| 0·4 | 16·3 | 19·9 | 23·6 | 27·2 | 30·9 | 34·5 | 38·2 | 41·8 | 45·5 | 49·1 | 52·8 |
| 0·5 | 17·4 | 21·2 | 25·0 | 28·8 | 32·6 | 36·3 | 40·1 | 43·9 | 47·7 | 51·5 | 55·2 |
| 0·6 | 18·7 | 22·6 | 26·5 | 30·4 | 34·4 | 38·3 | 42·2 | 46·1 | 50·2 | 54·0 | 57·9 |
| 0·7 | 20·0 | 24·2 | 28·1 | 32·2 | 36·3 | 40·4 | 44·4 | 48·5 | 52·6 | 56·7 | 60·7 |
| 0·8 | 21·4 | 25·7 | 29·9 | 34·1 | 38·4 | 42·6 | 46·9 | 51·1 | 55·3 | 59·6 | 63·8 |
| 0·9 | 23·0 | 27·4 | 31·8 | 36·2 | 40·6 | 45·0 | 49·5 | 53·9 | 58·3 | 62·7 | 67·1 |
| 1·0 | 24·6 | 29·3 | 33·9 | 38·5 | 43·1 | 47·7 | 52·3 | 56·9 | 61·5 | 66·1 | 70·7 |
| 1·1 | | 31·3 | 36·1 | 40·9 | 45·7 | 50·6 | 55·4 | 60·2 | 65·0 | 69·9 | 74·7 |
| 1·2 | | | 38·6 | 43·6 | 48·7 | 53·7 | 58·8 | 63·8 | 68·9 | 73·9 | 79·0 |
| 1·3 | | | | 46·6 | 51·9 | 57·2 | 62·5 | 67·8 | 73·1 | 78·4 | 83·7 |
| 1·4 | | | | | 55·4 | 61·0 | 66·6 | 72·2 | 77·7 | 83·3 | 88·9 |
| 1·5 | | | | | | 65·2 | 71·1 | 77·0 | 82·9 | 88·8 | 94·7 |

(including safety margin)

Based on $E_m = 1{\cdot}05\,[5{\cdot}67 + 0{\cdot}061\ W]$

$$\text{and } E_g = 1{\cdot}05 \left[\frac{\text{LWG}\ (6{\cdot}28 + 0{\cdot}0188\ W)}{(1 - 0{\cdot}3\ \text{LWG})}\right]$$

*Example 16*

Formulation of a ration for a 400 kg steer to gain 0.5 kg/day

Foods available: Hay MEF 8 MJ/kg DM
Cereal MEF 13 MJ/kg DM

APL = 1.26 (Table 12)
$NE_{mp}$ of hay = 4.7 MJ/kg DM (Table 13)
$NE_{mp}$ of cereal = 8.9 MJ/kg DM (Table 13)
Net energy requirement = 40.1 MJ/day (Table 14)

*Ration*

| | DMI (kg) | NE (MJ) |
|---|---|---|
| 6.6 kg hay DM at 4.7 MJ/kg | 6.6 | 31.0 |
| 1 kg cereal DM at 8.9 MJ/kg | 1.0 | 8.9 |
| | 7.6 | 39.9 |

*Example 17*

A 250 kg steer is required to gain 0.75 kg/day.

There is sufficient hay to feed 6 kg/day. How much cereal should be fed in addition?

Dry matter intake, DMI = 6.5 kg/day

Foods available: Hay 850 g/kg DM, MEF 8 MJ/kg DM

Cereal 860 g/kg DM, MEF 13 MJ/kg DM

APL = 1.50 (Table 12)

Net Energy required = 33.2 MJ/day (Table 14)

$$\text{At APL 1.5} \begin{cases} \text{Hay } NE_{mp} = 4.2 \text{ MJ/kg DM (Table 13)} \\ \text{Cereal } NE_{mp} = 8.6 \text{ MJ/kg DM (Table 13)} \end{cases}$$

*Ration*

| | | DMI (kg) | NE (MJ) |
|---|---|---|---|
| 6 kg hay, | (850 g/kg DM, 4.2 MJ/kg) | 5.1 | 21.4 |
| 1.6 kg cereal, | (860 g/kg DM, 8.6 MJ/kg) | 1.4 | 11.8 |
| | | 6.5 | 33.2 |

*Thus 1.6 kg cereal are required in addition to the 6 kg of hay to produce the required gain.*

RAPID RATION FORMULATION USING THE VARIABLE NET ENERGY SYSTEM

To formulate rapidly a ration from two components only, to meet the animal's expected dry matter intake, a minimum net energy concentration of the ration can be calculated from the net energy requirement and the probable dry matter intake, e.g.,
By the use of the data in *Example 17*,

$$\text{Minimum net energy concentration, N/D} = \frac{33.2}{6.5} = 5.11 \text{ MJ/kg DM}$$

A revised version of equation (23) can now be used, replacing

M/D by N/D

MF by $NE_{mp}$ of forage, NF

MC by $NE_{mp}$ of compound, NC

$$\text{Thus forage dry matter, FD} = \frac{\text{DMI (NC} - \text{N/D)}}{(\text{NC} - \text{NF})} \text{ kg} \qquad (35)$$

Continuing with *Example 17*

$$FD = \frac{6.5\ (8.6 - 5.11)}{(8.6 - 4.2)}$$

$$= 5.16 \text{ kg}$$

$$\text{and } CD = 6.5 - 5.16 = 1.34 \text{ kg}$$

A ration consisting of 6.1 kg of hay as fed and 1.6 kg of cereal as fed should give the required rate of gain.

### REPLACEMENT VALUES OF FOODS FOR GROWING AND FATTENING CATTLE

The relative values of foods are important when making decisions on their purchase or substitution in beef cattle rations. The variable net energy system provides an easy method for assessing the relative value of foods in a defined production situation.

*Example 18*

Calculation of the replacement value of two foods.

At APL 1.25 a feed A, of MEF 10 MJ/kg DM has a $NE_{mp}$ value of 6.4 MJ/kg
a feed B, of MEF 14 MJ/kg DM has a $NE_{mp}$ value of 9.7 MJ/kg
(Table 13)

*Hence* $\frac{9.7}{6.4}$ *kg DM of feed A, i.e. 1.5 kg, will replace 1 kg DM of feed B in a fattening ration at an APL of 1.25.*

At APL 1.75, feed A has a $NE_{mp}$ of 5.6 MJ/kg DM and feed B, 9.3 MJ/kg DM

*Thus* $\frac{9.3}{5.6}$ *= 1.7 kg DM of feed A are required to replace 1 kg DM of feed B.*

### LINEAR PROGRAMMING OF BEEF CATTLE RATIONS USING THE VARIABLE NET ENERGY SYSTEM

The matrix required for this purpose will have a number of entries under each food, of $NE_{mp}$ values for each APL level chosen, as in Table 13. Thus rows of $NE_{mp}$ values will be set up, each of which can only be used for net energy allowances from Table 14, at that APL value. Substitution rates and break-even prices will vary according to the APL chosen. It is suggested that APL = 1.25 could be used for rates of gain of 0.5 kg/day and below, and APL = 1.60 for high rates of gain, about 1 kg/day, but this will lead to some loss of precision.

The usual dry matter appetite constraints should, of course, be used.

### FINAL NOTE

The variable net energy system *cannot be used to predict animal performance*, since the animal's liveweight gain must be known in order to calculate APL and hence $NE_{mp}$ values. The ME system must be used for performance prediction as previously described.

## SUMMARY

## ME System for Beef Cattle

MAINTENANCE REQUIREMENTS with no allowance for activity:
(including safety margin)

$$M_m = 8.3 + 0.091\ W \qquad \text{(Table 1)}$$

PRODUCTION REQUIREMENTS

ME available for production: $MEP = MER - M_m$

Efficiency of ME utilisation for gain: $k_g = 0.0435\ M/D$

*Net energy stored:* $E_g = MEP \times k_g$

Allowing for 0.05 safety margin this becomes: $E_g = 0.0414\ M/D \times MEP$ (Table 8)

Energy value of gain: $EV_g = 6.28 + 0.3\ E_g + 0.0188\ W$

Since predicted liveweight gain, $LWG = \dfrac{E_g}{EV_g}$

$$\textit{Predicted LWG} = \frac{E_g}{(6.28 + 0.3\ E_g + 0.0188\ W)} \qquad \text{(Table 9)}$$

## Variable Net Energy System for Ration Formulation for Beef Cattle

NET ENERGY FOR MAINTENANCE

(including safety margin) $E_m = 1.05\ [5.67 + 0.061\ W]$ (Table 14)

NET ENERGY FOR LIVEWEIGHT GAIN

(including safety margin) $E_p = 1.05 \left[ \dfrac{LWG\ (6.28 + 0.0188\ W)}{(1 - 0.3\ LWG)} \right]$ (Table 14)

ANIMAL PRODUCTION LEVEL: $APL = \dfrac{E_m + E_p}{E_m}$ (Table 12)

Efficiency of ME utilisation for maintenance and production,

$$k_{mp} = \frac{MEF \times APL}{1.39\ MEF + 23\ (APL - 1)}$$

NET ENERGY FOR MAINTENANCE AND PRODUCTION

$$NE_{mp} = \frac{(MEF)^2 \times APL}{1.39\ MEF + 23\ (APL - 1)} \qquad \text{(Table 13)}$$

# SECTION IV

## Use of the Metabolisable Energy System for sheep

### Pregnant and Lactating Animals

The use of the metabolisable energy system for pregnant and lactating sheep is similar to that for dairy cows. Maintenance and production requirements are calculated separately and then summed to give the total requirement.

#### METABOLISABLE ENERGY ALLOWANCES FOR MAINTENANCE

The minimum requirement for energy for maintenance is equal to the fasting metabolism (FM) which may be calculated as follows:

$$\text{FM (MJ/day)} = 0.23\ W^{0.73}$$

The efficiency of utilisation of metabolisable energy for maintenance ($k_m$) for sheep has been taken as being constant at 0.70. For rapid calculation a linear relationship between the metabolisable energy requirement and liveweight may be assumed with little error. With the use of the usual 0.05 safety margin, the maintenance allowance for metabolisable energy for ewes kept *indoors* may be calculated as follows:

$$M_m = 1.4 + 0.09\ W \qquad (36)$$

An activity allowance of 0.15 of the fasting metabolism would seem to be justified for ewes living outdoors and the net energy requirement for maintenance is then

$$E_m = 0.265\ W^{0.73}$$

Using $k_m = 0.70$ and a 0.05 safety margin, the equation for calculating maintenance allowance for ewes *outdoors* becomes

$$M_m = 1.8 + 0.1\ W \qquad (37)$$

Maintenance allowances for ewes of various weights are given in Table 15.

#### METABOLISABLE ENERGY ALLOWANCES FOR PREGNANCY

Pregnancy increases total energy requirement, which is needed for two main purposes:

1. To provide the energy stored in the foetus, its associated membranes, and for the growth of uterine tissue, ($E_c$).
2. To allow for the 'Heat Increment of Gestation' (HIG). This is the additional output of heat that occurs during pregnancy and results from
   - (a) energy used to synthesize foetal and associated tissues
   - (b) energy needed to maintain the foetus plus the additional maintenance needs of the ewe resulting from the higher basal metabolism associated with pregnancy.

It is considered that half of the heat increment of gestation (HIG) may be allocated to each of (a) and (b). Hence the energy needs of pregnancy may be calculated as follows:

$$E_c + \frac{HIG}{2} + \frac{HIG}{2 \times k_m}$$

Since $k_m$ is 0.70, the efficiency of ME utilisation for maintenance, this becomes

$$E_c + 1.21\ HIG$$

Since by definition, ME = net energy + heat production, extra ME required for pregnancy = $E_c + 1.21$ HIG

Thus the total ME requirement for a pregnant ewe is given by

$$\text{ME required} = M_m + E_c + 1.21\ HIG \qquad (38)$$

As a basis for calculating the requirements for pregnant sheep, the birth-weights of lambs given in the table have been assumed (Donald and Russell, 1970)[1].

**Table E**

*Lamb birthweights*

| Ewe weight (kg) | Total lamb weight (kg) | |
|---|---|---|
| | Single | Twins |
| 40 | 3·4 | 5·4 |
| 50 | 3·9 | 6·4 |
| 60 | 4·5 | 7·3 |
| 70 | 5·0 | 8·2 |
| 80 | 5·5 | 9·0 |

Langlands and Sutherland (1968)[2] give estimates of energy stored ($E_c$) in foetal and associated tissues at various stages during pregnancy for lambs of 4.5 kg birthweight.

Estimates of energy stored for ewes of different weights have been calculated from the data of Langlands and those of Donald and Russell.

Langlands and Sutherland also gave values for the heat increment of gestation (HIG) at various stages of pregnancy for lambs of 4.5 kg birth-weights. Estimates for ewes of different weights have been calculated in a similar manner.

By the use of these estimates of $E_c$ and HIG for ewes of different weights, the total daily metabolisable energy requirements of pregnant ewes have been calculated as follows:

$$\text{ME Allowance (MJ/day)} = M_m + (E_c + 1.21\ HIG)\ 1.05$$

which includes the usual 0.05 safety margin on the ME required for pregnancy.

[1] Anim. Prod. **12**, 273, 1970 [2] Brit. J. Nutr. **22**, 217, 1968

The values so obtained are represented accurately by the fitted equations

*Ewes with single lambs*: $ME = (1.2 + 0.05\ W)e^{0.0072t}$ (39)

*Ewes with twin lambs*: $ME = (0.8 + 0.04\ W)e^{0.0105t}$ (40)

where t = number of days pregnant
and e = 2.718, the base of the natural logarithm

ME allowances for ewes of various bodyweights, (W) carrying either single or twin lambs are shown in Table 15

**Table 15**

*ME allowances (MJ/day) of pregnant ewes outdoors*

| Liveweight, W (kg) | Maintenance | Weeks before lambing | | | | |
|---|---|---|---|---|---|---|
| | | 8 | 6 | 4 | 2 | Birth |
| 30 S | 4·8 | 5·1 | 5·7 | 6·3 | 6·9 | 7·7 |
| T | *(− 0·7) | 5·1 | 5·9 | 6·8 | 7·9 | 9·2 |
| 40 S | 5·8 | 6·1 | 6·7 | 7·4 | 8·2 | 9·1 |
| T | *(− 0·8) | 6·1 | 7·1 | 8·2 | 9·5 | 11·0 |
| 50 S | 6·8 | 7·0 | 7·8 | 8·6 | 9·5 | 10·5 |
| T | *(− 0·9) | 7·1 | 8·3 | 9·6 | 11·1 | 12·8 |
| 60 S | 7·8 | 8·0 | 8·8 | 9·8 | 10·8 | 11·9 |
| T | *(− 1·0) | 8·1 | 9·4 | 10·9 | 12·7 | 14·7 |
| 70 S | 8·8 | 8·9 | 9·9 | 10·9 | 12·1 | 13·4 |
| T | *(− 1·1) | 9·2 | 10·6 | 12·3 | 14·2 | 16·5 |
| 80 S | 9·8 | 9·9 | 10·9 | 12·1 | 13·4 | 14·8 |
| T | *(− 1·2) | 10·2 | 11·8 | 13·7 | 15·8 | 18·3 |

(including safety margin)

*For ewes indoors decrease by allowance shown thus (− 1·2)

Based on $M_m = 1{\cdot}8 + 0{\cdot}1\ W$ (outdoors), $M_m = 1{\cdot}4 + 0{\cdot}09\ W$ (indoors)

S = singles: $M_{mp} = (1{\cdot}2 + 0{\cdot}05\ W)e^{0{\cdot}0072t}$

T = twins: $M_{mp} = (0{\cdot}8 + 0{\cdot}04\ W)e^{0{\cdot}0105t}$

(where t = number of days pregnant)

### FORMULATION OF A RATION FOR A PREGNANT EWE

The following information is needed before proceeding:

(a) liveweight of the ewe, W (kg)
(b) whether the ewe is expected to carry single or twin lambs
(c) number of weeks before lambing
(d) probable dry matter intake, DMI (kg/day)
(e) dry matter content, DM (g/kg), and ME content, MEF (MJ/kg), of the foods available.

then calculate:

(f) ME allowance for maintenance and pregnancy
(g) total DM and ME supplied by the foods making up the ration and to compare these with (d) and (f).

*Example 19*

Formulation of a ration for a 60 kg ewe carrying twin lambs due to lamb in 4 weeks time. The foods available are meadow hay, swedes and sheep compound.

Probable dry matter appetite = 1.1 kg/day

ME for maintenance and pregnancy = 10.9 MJ/day (Table 15)

*Ration*

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 0.75 kg hay, | (850 g/kg DM, 8 MJ/kg DM) | 0.64 | 5.1 |
| 2 kg swedes | (120 g/kg DM, 12.8 MJ/kg DM) | 0.24 | 3.1 |
| 0.25 kg sheep compound | (880 g/kg DM, 12.5 MJ/kg DM) | 0.22 | 2.7 |
| | | 1.10 | 10.9 |

METABOLISABLE ENERGY ALLOWANCES FOR LACTATION

The requirement for net energy for milk production is the energy content ($E_l$) of the milk secreted. This may be obtained from the yield of milk (Y) and its energy value ($EV_l$).

*Energy value of milk.*

An energy value ($EV_l$) of 4.6 MJ/kg has been adopted.

*Milk yield.*

The 12-week milk yields (Y) given in Table F have been assumed.

**Table F**

*Twelve week milk yields of ewes (kg)*

| Lambs suckled | Hill breeds | Lowland breeds |
|---|---|---|
| Single | 100 | 120 |
| Twins | 150 | 170 |

The milk yield distributions over the first month (Y1), second month (Y2) and third month (Y3) are given by:

| *Single lamb* | *Twin lambs* |
|---|---|
| Y1 = 0.374 Y | Y1 = 0.419 Y |
| Y2 = 0.361 Y | Y2 = 0.346 Y |
| Y3 = 0.265 Y | Y3 = 0.235 Y |

From these ratios, the average expected daily milk yields of lactating ewes have been calculated and are shown in Table 16.

**Table 16**

*Average milk yield, Y (kg/day) of lactating ewes*

| Breed | Lambs | Milk yield (kg/day) | | |
|---|---|---|---|---|
| | | Month 1 | Month 2 | Month 3 |
| Hill | Single | 1·34 | 1·29 | 0·95 |
| | Twins | 2·24 | 1·85 | 1·26 |
| Lowland | Single | 1·60 | 1·55 | 1·14 |
| | Twins | 2·54 | 2·10 | 1·43 |

**Table 17**

*ME allowances (MJ/day) for lactating hill ewes*

| Liveweight, W (kg) | Lambs | Stage of lactation | | |
|---|---|---|---|---|
| | | Month 1 | Month 2 | Month 3 |
| 30 | Single | 15·3 | 14·9 | 12·2 |
| | Twins | 22·3 | 19·2 | 14·6 |
| 40 | Single | 16·3 | 15·9 | 13·2 |
| | Twins | 23·3 | 20·2 | 15·6 |
| 50 | Single | 17·3 | 16·9 | 14·2 |
| | Twins | 24·3 | 21·2 | 16·6 |
| 60 | Single | 18·3 | 17·9 | 15·2 |
| | Twins | 25·3 | 22·2 | 17·6 |

(including safety margin)

**Table 18**

*ME allowances (MJ/day) for lactating lowland ewes*

| Liveweight, W (kg) | Lambs | Stage of lactation | | |
|---|---|---|---|---|
| | | Month 1 | Month 2 | Month 3 |
| 50 | Single | 19·3 | 18·9 | 15·7 |
| | Twins | 26·6 | 23·2 | 18·0 |
| 60 | Single | 20·3 | 19·9 | 16·7 |
| | Twins | 27·6 | 24·2 | 19·0 |
| 70 | Single | 21·3 | 20·9 | 17·7 |
| | Twins | 28·6 | 25·2 | 20·0 |
| 80 | Single | 22·3 | 21·9 | 18·7 |
| | Twins | 29·6 | 26·2 | 21·0 |

(including safety margin)

*Efficiency of utilisation of metabolisable energy for milk production.*

By analogy with the dairy cow, $k_l$ has been taken as 0.62. The metabolisable energy required to produce a kilogram of milk is then $4.6 \div 0.62 = 7.42$ MJ. Allowing the usual safety margin, this becomes 7.8 MJ/kg. The calculated total ME allowances for hill and lowland ewes with either single or twin lambs are shown in Tables 17 and 18.

FORMULATION OF A RATION FOR A LACTATING EWE

The information needed for this purpose is:

(a) liveweight of the ewe, W (kg)
(b) whether it is a hill or lowland ewe
(c) whether the ewe is suckling single or twin lambs
(d) stage of lactation
(e) expected dry matter appetite, DMI (kg)
(f) dry matter content, DM (g/kg) and ME content, MEF (MJ/kg), of the foods available

then calculate:

(g) ME allowance for maintenance, $M_m$ (MJ)
(h) ME allowance for lactation, $M_l$ (MJ)
(i) total ME allowance, $M_m + M_l$ (MJ)
(j) total DM and ME supplied by the foods making up the ration and compare these with (i) and (e)

*Example 20*

Formulation of a ration for a 40 kg hill ewe suckling a single lamb in the first month of lactation. The foods available are barn dried hay and oats.

Dry matter appetite = 1.6 kg/day

ME for maintenance $M_m$ = 5.8 MJ (Table 15)
Milk yield in 1st month = 1.34 kg/day (Table 16)
ME for lactation, $M_l$ = $1.34 \times 7.8 = 10.5$ MJ
*Total ME required* = $M_m + M_l = 5.8 + 10.5$
= *16.3 MJ/day* (Table 17)

*Ration*

| | DMI (kg) | ME (MJ) |
|---|---|---|
| 1.2 kg hay, (830 g/kg DM, 9.5 MJ/kg DM) | 1.00 | 9.5 |
| 0.7 kg oats, (860 g/kg DM, 11.5 MJ/kg DM) | 0.60 | 6.9 |
| | 1.60 | 16.4 |

*Note* If two foods only are involved in the ration, use can be made of equation (23) as in earlier sections:

$$FD = \frac{DMI\ (MC - M/D)}{(MC - MF)} \text{ kg/day} \tag{23}$$

The required energy concentration M/D for *Example 20* is

$$M/D = \frac{ME}{DMI} = \frac{16.3}{1.6} = 10.2 \text{ MJ/kg DM}$$

## Growing and Fattening Sheep

### THE USE OF THE METABOLISABLE ENERGY SYSTEM FOR PERFORMANCE PREDICTION

The efficiency of ME utilisation for maintenance, growth and fattening in lambs closely resembles that of growing cattle described in Section III. Equations defining net energy requirements for maintenance and gain will obviously be different, and will be detailed below.

### METABOLISABLE ENERGY ALLOWANCES FOR MAINTENANCE

*For animals kept indoors* the net energy required for maintenance ($E_m$) is equal to the fasting metabolism (FM) and may be calculated from the equation

$$E_m \text{ (MJ/day)} = 0.29\ W^{0.73} \tag{41}$$

The efficiency with which metabolisable energy is used for maintenance ($k_m$) is 0.70 and the requirement for metabolisable energy for maintenance is

$$\frac{E_m}{0.70} \text{ or } 1.43\ E_m$$

With the usual safety margin, the maintenance allowance becomes 0.435 $W^{0.73}$. For rapid calculation, a linear relationship between the allowance of metabolisable energy for maintenance and liveweight may be adopted with little loss of accuracy. The equation for calculating maintenance allowance is then

$$M_m = 1.2 + 0.13\ W \tag{42}$$

**Table 19**

*Maintenance allowances of growing sheep*

| Liveweight, W (kg) | ME allowance (MJ/day) | |
|---|---|---|
| | Indoors[1] | Outdoors[2] |
| 10 | 2·5 | 2·9 |
| 15 | 3·2 | 3·7 |
| 20 | 3·8 | 4·4 |
| 25 | 4·5 | 5·2 |
| 30 | 5·1 | 5·9 |
| 35 | 5·8 | 6·7 |
| 40 | 6·4 | 7·4 |
| 45 | 7·1 | 8·2 |
| 50 | 7·7 | 8·9 |

[1] Based on $M_m = 1{\cdot}2 + 0{\cdot}13\ W$ } including safety margin
[2] Based on $M_m = 1{\cdot}4 + 0{\cdot}15\ W$

*For animals kept outdoors* an activity increment of 0.15 of the fasting metabolism should be added and the metabolisable energy allowance for maintenance is then

$$M_m = 0.50\ W^{0.73}$$

For rapid calculation a linear relationship between the maintenance allowance and liveweight may be adopted with little loss of accuracy. The equation for calculating maintenance allowance then becomes

$$M_m = 1.4 + 0.15\ W \qquad (43)$$

Allowances of ME for maintenance (MJ/day) for growing and fattening sheep, both indoors and outdoors, are given in Table 19.

Where animals are kept under conditions involving additional expenditure of energy, e.g., under adverse climatic conditions or where food is scarce and extra foraging is required, it may be necessary to increase the maintenance allowances above those suggested.

PREDICTION OF LIVEWEIGHT GAIN

The efficiency with which the metabolisable energy available for production (MEP) is utilised for body gain ($k_g$) may be calculated as for cattle:

$$k_g = 0.0435\ M/D \qquad (8)$$

The energy stored ($E_g$) is then calculated as the product of metabolisable energy available for production (MEP) and its efficiency of utilisation ($k_g$), i.e.,

$$\text{Energy stored as gain } E_g = MEP \times k_g = MEP \times 0.0435\ M/D$$

Including the usual safety margin this becomes

$$E_g = MEP \times 0.0414\ M/D \qquad (27)$$

Values of energy stored for given amounts of metabolisable energy available for production, at various energy concentrations (M/D), are given in Table 20.

The weight gain that can be achieved from the energy stored can be calculated as follows:

$$LWG = \frac{\text{Energy stored}}{\text{Energy Value of gain}} = \frac{E_g}{EV_g}$$

*Energy value of gain*

The energy value of gains for lambs are given in Nutrient Requirements of Farm Livestock No 2 *Ruminants* ARC 1965, Appendix 6.2, Table 3 p.255. These values are accurately represented by the equation

$$\log_{10} EV_g = 0.11 \log_{10} LWG + 0.004W + 0.88\ (MJ/kg) \qquad (44)$$

where W is kg, and LWG is *g/day*

*Predicted liveweight gain*

With the substitution of $\frac{E_g}{LWG}$ for $EV_g$ equation (44) may be rearranged to give the following:

$$\log_{10} LWG = 0.9 \log_{10} E_g - 0.0036\ W + 1.91 \qquad (45)$$

Values for gain predicted from energy stored, ($E_g$) and bodyweight (W) are given in Table 21.

**Table 20**

*Energy stored $E_g$, for ME available MEP, at energy concentration M/D*

| MEP (MJ) | Energy concentration, M/D (MJ/kg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 2 | 0·7 | 0·7 | 0·8 | 0·9 | 1·0 | 1·1 | 1·2 |
| 4 | 1·3 | 1·5 | 1·7 | 1·8 | 2·0 | 2·2 | 2·3 |
| 6 | 2·0 | 2·2 | 2·5 | 2·7 | 3·0 | 3·2 | 3·5 |
| 8 | 2·6 | 3·0 | 3·3 | 3·6 | 4·0 | 4·3 | 4·6 |
| 10 | 3·3 | 3·7 | 4·1 | 4·6 | 5·0 | 5·4 | 5·8 |
| 12 | 4·0 | 4·5 | 5·0 | 5·5 | 6·0 | 6·5 | 7·0 |
| 14 | 4·6 | 5·2 | 5·8 | 6·4 | 7·0 | 7·5 | 8·1 |
| 16 | 5·3 | 6·0 | 6·6 | 7·3 | 7·9 | 8·6 | 9·3 |
| 18 | 6·0 | 6·7 | 7·5 | 8·2 | 8·9 | | |
| 20 | 6·6 | 7·5 | 8·3 | 9·1 | | | |

(including safety margin)

Based on $E_g = \text{MEP} \times 0{\cdot}0414\ \text{M/D}$

**Table 21**

*Predicted liveweight gain (g/day) from energy stored $E_g$, for liveweight, W*

| $E_g$ (MJ) | Liveweight, W (kg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 0·5 | 40 | 38 | 37 | 35 | 34 | 33 | 31 | 30 | 29 |
| 1·0 | 75 | 72 | 69 | 66 | 63 | 61 | 58 | 56 | 54 |
| 1·5 | 108 | 103 | 99 | 95 | 91 | 88 | 84 | 81 | 77 |
| 2·0 | 140 | 134 | 129 | 123 | 118 | 114 | 109 | 105 | 100 |
| 2·5 | 171 | 164 | 157 | 151 | 145 | 139 | 133 | 128 | 123 |
| 3.0 | 201 | 193 | 185 | 178 | 170 | 164 | 157 | 151 | 144 |
| 3·5 | 231 | 222 | 213 | 204 | 196 | 188 | 180 | 173 | 166 |
| 4·0 | 261 | 250 | 240 | 230 | 221 | 212 | 203 | 195 | 187 |
| 4·5 | 290 | 278 | 267 | 256 | 245 | 236 | 226 | 217 | 208 |
| 5·0 | | 306 | 293 | 282 | 270 | 259 | 249 | 239 | 229 |
| 5·5 | | | 320 | 307 | 294 | 282 | 271 | 260 | 249 |
| 6·0 | | | 346 | 332 | 318 | 305 | 293 | 281 | 270 |
| 6·5 | | | | 357 | 342 | 328 | 315 | 302 | 290 |
| 7·0 | | | | 381 | 365 | 351 | 337 | 323 | 310 |
| 7·5 | | | | 406 | 389 | 373 | 358 | 344 | 330 |
| 8·0 | | | | | 412 | 396 | 380 | 364 | 349 |
| 8·5 | | | | | 435 | 418 | 401 | 386 | 369 |
| 9·0 | | | | | | 440 | 422 | 405 | 388 |

Based on $\log_{10} \text{LWG} = 0{\cdot}9 \log_{10} E_g - 0{\cdot}0036W + 1{\cdot}91$

PREDICTION OF THE LIVEWEIGHT GAIN OF GROWING SHEEP

This can be done in a similar manner to that for beef cattle.
It is necessary to know the following:

(a) liveweight of the animal, W (kg)
(b) total metabolisable energy supplied by the ration, MER (MJ)
(c) dry matter content of the ration, DM (kg)

and to calculate:

(d) metabolisable energy concentration of the ration, M/D (MJ/kg DM)
(e) metabolisable energy required for maintenance, $M_m$ (MJ)
(f) metabolisable energy available for production, MEP (MJ)
(g) net energy available for production, $E_g$ (MJ)
(h) predicted liveweight gain, LWG (g/day)

*Example 21*

Prediction of the liveweight gain of a lamb weighing 40 kg kept indoors, receiving the following ration:

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 0.75 kg hay, | (830 g/kg DM, 8 MJ/kg DM) | 0.62 | 5.0 |
| 0.70 kg compound, | (880 g/kg DM, 12 MJ/kg DM) | 0.62 | 7.4 |
| | | 1.24 | 12.4 |

$$\text{Ration energy concentration M/D} = \frac{12.4}{1.24} = 10 \text{ MJ/kg DM}$$

$$\text{Maintenance ME, } M_m = 6.4 \text{ MJ (Table 19)}$$

The metabolisable energy available for production can be found by deducting that required for maintenance from the total metabolisable energy of the ration.

$$\begin{aligned} \text{ME available for liveweight gain, MEP} = \text{MER} - M_m &= 12.4 - 6.4 \\ &= 6 \text{ MJ} \end{aligned}$$

$$\begin{aligned} \text{Energy stored as gain, } E_g &= \text{MEP} \times 0.0414 \times \text{M/D} \\ &= 6 \times 0.0414 \times 10 \\ &= 2.5 \text{ MJ (Table 20)} \\ \textit{Predicted liveweight gain LWG} &= \textit{133 g/day} \text{ (Table 21)} \end{aligned}$$

*Example 22*

Prediction of the liveweight gain of a 25 kg lamb kept outdoors, receiving a ration consisting of:

| | | DMI (kg) | ME (MJ) |
|---|---|---|---|
| 2.5 kg silage, | (200 g/kg DM, 9.5 MJ/kg DM) | 0.50 | 4.8 |
| 1.0 kg swedes, | (110 g/kg DM, 12.8 MJ/kg DM) | 0.11 | 1.4 |
| 0.3 kg compound, | (860 g/kg DM, 12.5 MJ/kg DM) | 0.26 | 3.2 |
| | | 0.87 | 9.4 |

$$\text{MER} = 9.4 \text{ MJ/day}$$

$$\text{M/D} = \frac{9.4}{0.87} = 10.8 \text{ MJ/kg DM}$$

$$M_m = 5.2 \text{ MJ (Table 19)}$$

$$\text{MEP} = 9.4 - 5.2 = 4.2 \text{ MJ}$$

$$E_g = 4.2 \times 0.0414 \times 10.8 = 1.9 \text{ MJ (Table 20)}$$

$$\textit{LWG} = \textit{116 g/day} \text{ (Table 21)}$$

METABOLISABLE ENERGY ALLOWANCES FOR GROWING AND FATTENING LAMBS

The total ME allowances for growing lambs can be calculated by summing the allowance for maintenance ($M_m$) given by equations (42) and (43) and the ME for production ($M_g$) which is given by

$$M_g = \frac{E_g}{0.0414 \ \text{M/D}} \tag{27}$$

Estimates of the total ME allowances for lambs of different weights, gaining at different daily rates, on rations of different energy concentration (M/D), are given in Table 22. An increase in maintenance of 0.15 for *outdoor* fed sheep is also shown in Table 22.

**The Use of the Variable Net Energy System for Growing and Fattening Sheep**

This system states the allowances of the animal in terms of net energy. Net energies are calculated for each food, at the relevant level of animal production, and used, in conjunction with the estimates of requirements, to formulate rations. The system is additive and ideal for linear programme work. Replacement values can be calculated without the iterative approach necessary with the metabolisable energy system.

NET ENERGY ALLOWANCE FOR MAINTENANCE

*Animals kept indoors* The net energy allowance for maintenance ($E_m$) may be calculated from equation (41),

$$E_m \text{ (MJ/day)} = 0.29 \ W^{0.73} \tag{41}$$

If a safety margin of 0.05 is used the daily net energy allowance for maintenance becomes

$$E_m \text{ (MJ/day)} = 0.3045 \ W^{0.73}$$

For rapid calculation a linear relationship between liveweight and net energy allowance for maintenance may be assumed with little loss of accuracy. The equation for calculating maintenance allowance is then

$$E_m \text{ (MJ/day)} = 0.84 + 0.091 \ W \tag{46}$$

*Animals kept outdoors* For such animals an activity increment of 0.15 of the fasting metabolism may be added and the net energy allowance for maintenance, ($E_m$) may be calculated by the following equation:

$$E_m \text{ (MJ/day)} = 0.3502 \ W^{0.73}$$

For rapid calculation a linear relationship between weight and daily net energy allowance for maintenance may be assumed. The equation for calculating maintenance allowance is then

$$E_m \text{ (MJ/day)} = 1.1 + 0.1 \ W \tag{47}$$

**Table 22**

*Daily ME allowances (MJ/day) for indoor fed growing sheep*

| Liveweight (kg) | Ration M/D (MJ/kg) | Rate of gain (g/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 |
| | 8 | 4·4 | | | | | | | |
| | 10 | 4·0 | 5·8 | | | | | | |
| 10 | 12 | 3·8 | 5·3 | 6·9 | | | | | |
| (+ 0·4)* | 14 | 3·6 | 4·9 | 6·2 | | | | | |
| | 8 | 5·2 | 7·5 | | | | | | |
| | 10 | 4·8 | 6·6 | 8·6 | | | | | |
| 15 | 12 | 4·5 | 6·1 | 7·7 | 9·4 | | | | |
| (+ 0·5)* | 14 | 4·3 | 5·6 | 7·1 | 8·5 | | | | |
| | 8 | 5·9 | 8·4 | 11·0 | | | | | |
| | 10 | 5·5 | 7·5 | 9·5 | 11·7 | | | | |
| 20 | 12 | 5·2 | 6·8 | 8·6 | 10·4 | 12·2 | 14·1 | | |
| (+ 0·6)* | 14 | 5·0 | 6·4 | 7·9 | 9·4 | 11·0 | 12·6 | | |
| | 8 | 6·7 | 9·2 | 12·0 | | | | | |
| | 10 | 6·2 | 8·3 | 10·5 | 12·7 | 15·0 | | | |
| 25 | 12 | 5·9 | 7·6 | 9·5 | 11·3 | 13·3 | 15·3 | 17·3 | |
| (+ 0·7)* | 14 | 5·7 | 7·2 | 8·7 | 10·4 | 12·0 | 13·7 | 15·4 | |
| | 8 | 7·4 | 10·1 | 13·0 | | | | | |
| | 10 | 7·0 | 9·1 | 11·4 | 13·8 | 16·2 | | | |
| 30 | 12 | 6·6 | 8·4 | 10·3 | 12·3 | 14·3 | 16·4 | 18·5 | |
| (+ 0·8)* | 14 | 6·4 | 8·0 | 9·6 | 11·3 | 13·0 | 14·8 | 16·6 | |
| | 8 | 8·2 | 11·0 | 14·0 | 17·1 | | | | |
| | 10 | 7·7 | 9·9 | 12·3 | 14·8 | 17·4 | 20·0 | | |
| 35 | 12 | 7·4 | 9·2 | 11·2 | 13·3 | 15·4 | 17·6 | 19·8 | 22·1 |
| (+ 0·9)* | 14 | 7·1 | 8·7 | 10·5 | 12·2 | 14·0 | 15·9 | 17·8 | 19·7 |
| | 8 | 8·9 | 11·9 | 15·0 | 18·3 | | | | |
| | 10 | 8·4 | 10·8 | 13·3 | 15·9 | 18·6 | 21·3 | | |
| 40 | 12 | 8·1 | 10·1 | 12·1 | 14·3 | 16·5 | 18·8 | 21·1 | 23·5 |
| (+ 1·0)* | 14 | 7·9 | 9·5 | 11·3 | 13·2 | 15·1 | 17·0 | 19·0 | 21·0 |
| | 8 | 9·7 | 12·8 | 16·1 | 19·5 | | | | |
| | 10 | 9·2 | 11·7 | 14·3 | 17·0 | 19·8 | 22·6 | | |
| 45 | 12 | 8·8 | 10·9 | 13·1 | 15·3 | 17·7 | 20·0 | 22·5 | 24·9 |
| (+ 1·1)* | 14 | 8·6 | 10·3 | 12·2 | 14·1 | 16·1 | 18·2 | 20·2 | 22·4 |
| | 8 | 10·5 | 13·7 | 17·2 | 20·7 | | | | |
| | 10 | 9·9 | 12·5 | 15·3 | 18·1 | 21·0 | 24·0 | | |
| 50 | 12 | 9·6 | 11·7 | 14·0 | 16·4 | 18·8 | 21·3 | 23·8 | 26·4 |
| (+ 1·2)* | 14 | 9·3 | 11·1 | 13·1 | 15·1 | 17·2 | 19·4 | 21·5 | 23·7 |

(including safety margin)

*Outdoor fed growing sheep, increase in maintenance allowance of 0·15 indicated as MJ/head daily thus (+ 0·8)

### NET ENERGY ALLOWANCE FOR LIVEWEIGHT GAIN

The net energy required for production ($E_p$) is the energy stored in liveweight gain, which is the product of the gain (LWG) and its energy value ($EV_g$). The energy stored as gain in sheep ($E_p$) may be calculated from the following equation:

$$\log_{10} E_p = 1.11 \log_{10} LWG + 0.004\ W - 2.10 \qquad (48)$$

where LWG is *g/day* and a safety margin is included.

The maintenance allowances may be combined with estimates of production to give the total daily net energy allowance shown in Table 23.

### ANIMAL PRODUCTION LEVEL

In the metabolisable energy system for lambs, the efficiency of utilisation of metabolisable energy for maintenance is fixed at 0.70 while the efficiency for growth is dependent upon the dietary metabolisable energy concentration:

$$k_g = 0.0435\ M/D \qquad (8)$$

The overall efficiency of utilisation of metabolisable energy for maintenance and growth ($k_{mp}$) depends upon the proportions of the energy used for the two functions and upon the dietary metabolisable energy concentration (M/D). At any given value of M/D and level of production, defined relative to maintenance, $k_{mp}$ will be constant.
The level of production relative to maintenance is referred to as the Animal Production Level and is defined as the ratio between maintenance and production requirements in terms of their net energies. APL may be calculated as follows:

$$APL = \frac{E_m + E_p}{E_m} \qquad (19)$$

exactly as defined in Section III on beef cattle. In this case however $E_m$ is defined by equations (46) or (47) and $E_p$ by equation (48) above.
Values for APL at different liveweights and daily weight gains for sheep kept indoors are shown in Table 24. At the maintenance level, when gain is zero, APL = 1.0

*Animals kept outdoors* Owing to the inclusion of an activity increment for animals kept outdoors, values of APL will be slightly lower than for comparable animals kept indoors. The effect on the net energy values of food is negligible (*circa* 0.1 MJ/kg) and the values given in Table 25 can be used in outdoor situations.

**Table 23**

*Net energy allowances (MJ) of growing lambs (indoors)*

| LWG (g/day) | Liveweight, W (kg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 50 | 2·4 | 2·9 | 3·4 | 3·9 | 4·4 | 4·9 | 5·4 | 5·9 | 6·4 |
| 100 | 3·2 | 3·7 | 4·2 | 4·8 | 5·3 | 5·8 | 6·4 | 6·9 | 7·5 |
| 150 | 4·0 | 4·6 | 5·2 | 5·7 | 6·3 | 6·9 | 7·5 | 8·1 | 8·7 |
| 200 | 4·9 | 5·5 | 6·1 | 6·7 | 7·3 | 8·0 | 8·6 | 9·3 | 9·9 |
| 250 | 5·8 | 6·4 | 7·1 | 7·7 | 8·4 | 9·1 | 9·8 | 10·5 | 11·2 |
| 300 | | 7·3 | 8·0 | 8·8 | 9·5 | 10·2 | 11·0 | 11·7 | 12·5 |
| 350 | | | 9·0 | 9·8 | 10·6 | 11·4 | 12·2 | 13·0 | 13·8 |
| 400 | | | | 10·9 | 11·7 | 12·5 | 13·4 | 14·3 | 15·2 |
| Outdoors | +0·3 | +0·4 | +0·4 | +0·5 | +0·5 | +0·6 | +0·6 | +0·7 | +0·7 |

(including safety margin)

Requirements for lambs *outdoors* should be increased by amounts shown in final row at base of table.

**Table 24**

*Animal production levels for growing sheep*

| LWG (g/day) | Liveweight, W (kg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 50 | 1·38 | 1·32 | 1·28 | 1·25 | 1·23 | 1·21 | 1·20 | 1·19 | 1·18 |
| 100 | 1·83 | 1·69 | 1·60 | 1·53 | 1·49 | 1·45 | 1·43 | 1·41 | 1·39 |
| 150 | 2·30 | 2·08 | 1·94 | 1·84 | 1·77 | 1·71 | 1·67 | 1·64 | 1·61 |
| 200 | 2·79 | 2·49 | 2·29 | 2·15 | 2·05 | 1·98 | 1·92 | 1·88 | 1·84 |
| 250 | 3·29 | 2·90 | 2·65 | 2·48 | 2·35 | 2·25 | 2·18 | 2·12 | 2·08 |
| 300 | | 3·33 | 3·02 | 2·81 | 2·65 | 2·54 | 2·44 | 2·37 | 2·32 |
| 350 | | | 3·40 | 3·15 | 2·96 | 2·82 | 2·71 | 2·63 | 2·56 |
| 400 | | | | 3·49 | 3·27 | 3·11 | 2·99 | 2·89 | 2·81 |

Based on $\text{APL} = \dfrac{E_m + E_p}{E_m}$

*Efficiency of utilisation of metabolisable energy for maintenance and production*

The efficiency of utilisation of metabolisable energy for the combined function of maintenance and gain ($k_{mp}$) may be calculated as follows:

$$k_{mp} = \frac{E_m + E_p}{M_m + M_p} \tag{32}$$

$$M_m = \frac{E_m}{0.70}$$

$$M_p = \frac{E_p}{0.0435 \ M/D}$$

Since $$APL = \frac{E_m + E_p}{E_m}, \text{ then } E_p = E_m\,(APL - 1)$$

$$M_p = \frac{E_m\,(APL - 1)}{0.0435 \ M/D}$$

**Table 25**

*Net energy values for maintenance and production, $NE_{mp}$ (MJ/kg DM)*

| APL | Metabolisable energy of food, MEF (MJ/kg DM) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1·0 | 5·6 | 6·3 | 7·0 | 7·7 | 8·4 | 9·1 | 9·8 |
| 1·1 | 5·1 | 5·9 | 6·6 | 7·4 | 8·1 | 8·9 | 9·7 |
| 1·2 | 4·8 | 5·6 | 6·3 | 7·1 | 7·9 | 8·7 | 9·6 |
| 1·3 | 4·5 | 5·3 | 6·1 | 7·0 | 7·8 | 8·6 | 9·5 |
| 1·4 | 4·3 | 5·1 | 6·0 | 6·8 | 7·6 | 8·5 | 9·4 |
| 1·5 | 4·2 | 5·0 | 5·8 | 6·7 | 7·5 | 8·4 | 9·3 |
| 1·6 | 4·1 | 4·9 | 5·7 | 6·6 | 7·4 | 8·3 | 9·3 |
| 1·7 | 4·0 | 4·8 | 5·6 | 6·5 | 7·4 | 8·3 | 9·2 |
| 1·8 | 3·9 | 4·7 | 5·5 | 6·4 | 7·3 | 8·2 | 9·2 |
| 1·9 | 3·8 | 4·6 | 5·4 | 6·3 | 7·2 | 8·2 | 9·1 |
| 2·0 | 3·7 | 4·5 | 5·4 | 6·2 | 7·2 | 8·1 | 9·1 |
| 2·2 | 3·6 | 4·4 | 5·3 | 6·1 | 7·1 | 8·0 | 9·1 |
| 2·4 | 3·5 | 4·3 | 5·2 | 6·1 | 7·0 | 8·0 | 9·0 |
| 2·6 | 3·4 | 4·2 | 5·1 | 6·0 | 6·9 | 7·9 | 9·0 |
| 2·8 | 3·4 | 4·2 | 5·0 | 5·9 | 6·9 | 7·9 | 8·9 |
| 3·0 | 3·3 | 4·1 | 5·0 | 5·9 | 6·8 | 7·8 | 8·9 |

Based on $$NE_{mp} = \frac{(MEF)^2 \times APL}{1{\cdot}43\ MEF + 23\,(APL - 1)}$$

Substituting in $k_{mp} = \dfrac{E_m + E_p}{M_m + M_p}$ and rearranging,

$$k_{mp} = \frac{M/D \times APL}{1.43\ M/D + 23\ (APL - 1)} \tag{49}$$

NET ENERGY VALUES OF FOODS FOR MAINTENANCE AND PRODUCTION

The $k_{mp}$ values may be used to calculate net energies for maintenance and production ($NE_{mp}$) for either foods or rations as follows:

$$NE_{mp} = MEF \times k_{mp}$$

$$= \frac{(MEF)^2 \times APL}{1.43\ MEF + 23\ (APL - 1)} \tag{50}$$

Values for $NE_{mp}$ for different values of APL and MEF are given in Table 25.

USE OF THE VARIABLE NET ENERGY SYSTEM FOR RATION FORMULATION FOR SHEEP

Within dry matter appetite limits, rations for growing sheep can be constructed in a simple additive manner by using the appropriate $NE_{mp}$ values for the desired animal production level. In order to do this, it is necessary to know the following:

(a) animal's liveweight, W (kg)
(b) required rate of liveweight gain, LWG (g/day)
(c) expected dry matter intake, DMI (kg/day)
(d) food dry matter content, DM (g/kg)
 and ME content, MEF (MJ/kg DM)

and to calculate:

(e) required animal production level, APL
(f) net energy allowance for maintenance and gain (MJ/day)
(g) appropriate $NE_{mp}$ values for each food (MJ/kg DM)
and to formulate a ration which meets the values in (f) and (c)

*Example 23*

Formulation of a ration for a 35 kg lamb to gain 100 g/day

Foods available, hay, MEF 8 MJ/kg DM
cereal, MEF 13 MJ/kg DM
Dry matter intake, DMI = 1.0 kg/day
Net energy required for maintenance, $E_m$ = 4.0 MJ
gain, $E_g$ = 1.8 MJ
5.8 MJ (Table 23)

Animal production level $= \dfrac{5.8}{4.0} = 1.45$ (Table 24)

$NE_{mp}$ of hay, (MEF 8 MJ/kg DM) = 4.2 MJ/kg DM
$NE_{mp}$ of cereal, (MEF 13 ME/kg DM) = 8.4 MJ/kg DM (Table 25)

*Ration*

| | DMI (kg) | NE (MJ) |
|---|---|---|
| 0.6 kg Hay DM, 4.2 MJ/kg | 0.60 | 2.5 |
| 0.4 kg Cereal DM, 8.4 MJ/kg | 0.40 | 3.4 |
| | 1.00 | 5.9 |

If both hay and cereal have dry matter contents of 850 g/kg the required ration is 0.71 kg hay and 0.47 kg cereal

CALCULATION OF REPLACEMENT VALUES OF FOODS

*Example 24*

What is the replacement value of hay, (8 MJ/kg DM) for maize (14 MJ/kg DM) when fed to:

(a) a 25 kg lamb growing at 200 g/day

(b) a 35 kg lamb growing at 150 g/day?

(a) Animal production level = 2.15 (Table 24)

Hay, $NE_{mp}$ = 3.6 MJ/kg DM (Table 25)
Maize $NE_{mp}$ = 9.1 MJ/kg DM

$$\textit{Replacement value of hay for maize} = \frac{9.1}{3.6} = 2.53$$

(b) APL = 1.71

Hay $NE_{mp}$ = 4.0

Maize $NE_{mp}$ = 9.2

$$\textit{Replacement value} = \frac{9.2}{4.0} = 2.30$$

## SUMMARY

## ME System for Pregnant Ewes

MAINTENANCE REQUIREMENT: $M_m = 1.8 + 0.1\ W$ (outdoors)
(including safety margin) $M_m = 1.4 + 0.09\ W$ (indoors) (Table 15)

ME REQUIRED FOR MAINTENANCE AND PREGNANCY

*Ewes with single lambs:* $M_{mp} = (1.2 + 0.05\ W)e^{0.0072t}$ (Table 15)
(including safety margin)

*Ewes with twin lambs:* $M_{mp} = (0.8 + 0.04\ W)e^{0.0105t}$ (Table 15)
(including safety margin)

where t = number of days pregnant

## ME System for Lactating Ewes

MAINTENANCE REQUIREMENT: $M_m = 1.8 + 0.1\ W$ (outdoors) (Table 15)
(including safety margin) $M_m = 1.4 + 0.09\ W$ (indoors)

PRODUCTION REQUIREMENTS:

*Energy value of milk:* $EV_l = 4.6$ MJ/kg

*Energy secreted as milk:* $E_l = 4.6\ Y$ MJ/day

Efficiency of ME utilisation for lactation: $k_l = 0.62$

*ME required for milk:* $M_l = 7.8\ Y$ MJ/kg
(including safety margin)

## ME System for Growing Sheep

MAINTENANCE REQUIREMENT: $M_m = 1.2 + 0.13\ W$ (indoors) (Table 19)
(including safety margin) $M_m = 1.4 + 0.15\ W$ (outdoors)

PRODUCTION REQUIREMENTS:

ME available for liveweight gain: $MEP = MER - M_m$

Efficiency of utilisation of ME for gain: $k_g = 0.0435\ M/D$

*Energy stored as gain:* $E_g = MEP \times k_g = MEP \times 0.0435\ M/D$
or $MEP \times 0.0414\ M/D$ (Table 20)
(including safety margin)

Energy value of gain: $\log_{10} EV_g = 0.11 \log_{10} LWG + 0.004\ W + 0.88$ (MJ/kg)

*Predicted liveweight gain:* $\log_{10} LWG = 0.9 \log_{10} E_g - 0.0036\ W + 1.91$
where LWG is *g/day* (Table 21)

## Variable Net Energy System for Growing Sheep

NET ENERGY FOR MAINTENANCE
(including safety margin) $E_m = 0.84 + 0.091\ W$ MJ/day (indoors)
$E_m = 1.10 + 0.1\ W$ MJ/day (outdoors)

NET ENERGY FOR LIVEWEIGHT GAIN
(including safety margin)

$\text{Log}_{10} E_p = 1.11 \log_{10} LWG + 0.004\ W - 2.10$ MJ/day (Table 23)

ANIMAL PRODUCTION LEVEL: $APL = \dfrac{E_m + E_p}{E_m}$ (Table 24)

Efficiency of ME utilisation for maintenance and production

$$k_{mp} = \frac{M/D \times APL}{1.43\ M/D + 23\ (APL - 1)}$$

NET ENERGY FOR MAINTENANCE AND PRODUCTION

$$NE_{mp} = \frac{(MEF)^2 \times APL}{1.43\ MEF + 23\ (APL - 1)}\ \text{MJ/kg} \quad \text{(Table 25)}$$

# SECTION V

## Calculation of the Metabolisable Energies of Foods

### Energy Values of Foods

The starting point for the measurement or calculation of the metabolisable energy (ME) of a food is its gross energy or energy value (EV). This can be measured in a bomb calorimeter as MJ/kg dry matter, or calculated from a knowledge of its chemical composition by use of the following equation:

$$\text{EV (MJ/kg DM)} = 0.0226\ \text{CP} + 0.0407\ \text{EE} + 0.0192\ \text{CF} + 0.0177\ \text{NFE} \qquad (51)$$

$$\text{where}\quad \left.\begin{array}{ll} \text{CP} & \text{is crude protein } (\text{N} \times 6.25) \\ \text{EE} & \text{is ether extract} \\ \text{CF} & \text{is crude fibre} \\ \text{NFE} & \text{is nitrogen free extractives} \end{array}\right\} \begin{array}{l} \textit{all as g/kg DM} \\ (= 10 \times \%\ \text{in DM}) \end{array}$$

This equation was published by workers at the Oskar Kellner Institute, GDR, and has a low residual standard deviation ($\pm$ 0.2 MJ/kg). Values for gross energy in the tables of food composition, which follow, have been calculated from this equation.

The higher coefficients for ether extract (oils and fats) and also crude protein result in higher energy values for feeds containing large amounts of these two components. The majority of foods given to cattle and sheep are low in ether extract and the mean energy value calculated from equation (51) is 18.1 MJ/kg DM. Oil seeds, legumes, oil cakes and meals, and animal by-products which may be high in oil and/or protein have values of 20 to 26 MJ/kg.

Measured gross energies of foods have in the past been taken to average 4.4 kcal/g DM, equivalent to 18.4 MJ/kg DM. Measurements on grass hay agree exactly with this value, but recent measurements on grass silage averaged 20 MJ/kg DM when volatile compounds were included.

### Digestibility Measurements on Foods

The results of *in vivo* digestibility trials are available in publications such as Morrison's *Feeds and Feeding*, Schneider's *Feeds of the World*, formerly in MAFF Bulletin 48 *Rations for Livestock*, and latterly in ADAS Advisory Paper No 11, *Nutrient Allowances and Composition of Feedingstuffs for Ruminants*. Values are given for digestible nutrients as percentages; alternatively the digestibility coefficients of the nutrients are quoted alongside the chemical composition of the food, as in the tables which follow at the end of this section.

Digestible crude protein (DCP, g/kg DM) values are quoted in the tables because they are normally required for ration calculations.

Other methods of expressing digestibility are:

$$\%\ \text{Digestibility of the dry matter (DMD)} = \frac{(\text{Food DM} - \text{Faeces DM})}{\text{Food DM}} \times 100 \qquad (52)$$

$$\%\ \text{Digestibility of the organic matter (OMD)} = \frac{(\text{Food OM} - \text{Faeces OM})}{\text{Food OM}} \times 100 \qquad (53)$$

$$\% \text{ Digestible organic matter in dry matter (DOMD)} = \frac{(\text{Food OM} - \text{Faeces OM})}{\text{Food DM}} \times 100 \qquad (54)$$

Care must be exercised in using or comparing results to ensure that the relevant unit is being used.

Equation (52) for DMD avoids the need for total ash measurements of the food and residue, but introduces a source of error since ash has no energy value and can be very variable.

Equation (53) for OMD is often used for research purposes since it eliminates ash variation from comparisons of digestibilities. However OMD values can be applied only to food intake expressed as organic matter and this is rarely done.

It follows that OMD values can be converted to DOMD values if the ash content of the food is known:

$$\text{DOMD }\% = \frac{\text{OMD }\%\,(100 - \text{Ash }\%)}{100} \qquad (55)$$

The most useful method of expression for food evaluation purposes is DOMD, which enables the calculation of ME as MJ/kg DM directly. In the tables which follow *in vivo* DOMD (D values) have been calculated by summing the digestible nutrients, but have been stated as percentages and not as g/kg DM so as to give a link with previous methods of expressing food values.

### DIGESTIBLE ENERGY VALUES OF FOODS

Direct measurements of the digestible energy (DE) of foods are fairly widely recorded since it only requires the measurement of the energy value of the food and associated faeces from an *in vivo* digestibility trial. Calculation of DE values from DOMD values requires that the energy value of digested organic matter (DOM) be available e.g. 18.7 MJ/kg for dried grass. Another method is to calculate the value from an equation for grass and fresh maize recently proposed by Osbourn and his colleagues at the Grassland Research Institute:

Grass and fresh maize

$$\text{EV of DOM} = 0.0124\ \text{CP} + 17.3\ (\text{MJ/kg}) \qquad (56)$$

where CP is g/kg DM

In general the following equation can be used for the calculation of digestible energy values:

$$\text{DE} = 0.19\ \text{DOMD}\%\ (\text{MJ/kg DM}) \qquad (57)$$

## Metabolisable Energy Values of Foods

The metabolisable energy of a food (MEF) is defined as

$$\text{MEF} = \text{DE} - (\text{methane energy} + \text{urine energy})$$

As indicated in Section I, the sum of methane and urine energy is reasonably constant as a proportion of digested energy; averaging 0.19.

$$\text{Thus, ME} = 0.81\ \text{DE} \qquad (1)$$

The use of an average value for the energy value of digested organic matter of 19 MJ/kg gives the following general equation:

$$\text{MEF} = 0.15 \text{ DOMD } \% \qquad (58)$$

This simple linear relationship is demonstrated in the following table G.

**Table G**

*ME values of foods derived from DOMD % values*

| DOMD % | MEF, (MJ/kg DM) |
|---|---|
| 40 | 6·00 |
| 45 | 6·75 |
| 50 | 7·50 |
| 55 | 8·25 |
| 60 | 9·00 |
| 65 | 9·75 |
| 70 | 10·50 |
| 75 | 11·25 |
| 80 | 12·00 |
| 85 | 12·75 |

The ME values listed in the standard tables have been calculated from details of digestible proximate constituents given in ADAS Advisory Paper No. 11 by the use of the conversion factors proposed by the Oskar Kellner Institute, Rostock viz.

ME (MJ/kg)

$$= 0.0152 \text{ DCP} + 0.0342 \text{ DEE} + 0.0128 \text{ DCF} + 0.0159 \text{ DNFE} \qquad (2)$$

where DCP is digestible crude protein
DEE is digestible ether extract
DCF is digestible crude fibre
DNFE is digestible nitrogen free extract
} *all as g/kg DM* (= 10 × % in DM)

The use of this equation was demonstrated in Section I. It has a residual standard deviation of $\pm$ 0.3 MJ/kg.

Relatively few directly determined values for the ME content of foods are available and the Tables of Food Composition which follow result essentially from a recalculation of existing digestibility data. Revision of these tables must await the accumulation of new data from food evaluation units set up for this purpose.

The values listed fall into three categories:

1. Values for foods such as barley, maize and soya bean meal that vary little in ME value. The figures quoted are sound averages that are applicable generally. This applies to most foods in Sections 1, 12, 13 and 14 of the Food Composition Tables.

2. Values for less common foods which are representative examples but which may not have general application, e.g. Sections 7 and 15.

3. Values for forages like hay, silage etc that vary considerably in ME value. The figures quoted are examples only of ME values that might be found for groups of foods of these types.

This last group requires special attention because forages may supply over half of the dry matter of a ration. Consequently variations in ME values influence both ME intake and the M/D value of the diet considerably. More accurate knowledge of the ME of forages available for an individual feeding situation is desirable.

### PREDICTION OF THE METABOLISABLE ENERGY VALUES OF FORAGES

ME values of forages may be predicted from chemical analysis or by using *in vitro* digestibility techniques to provide figures from which ME values may be calculated from appropriate regression equations.
The equations available are of 3 types:

1. Those that derive ME from measured DE values for a food:

$$\text{MEF} = 0.81 \text{ DE} \tag{1}$$

2. Those that predict ME from digestibility values, DOMD %:

$$\text{MEF} = 0.15 \text{ DOMD } \% \tag{58}$$

where DOMD % can be *in vivo* or calculated from *in vitro* laboratory results.

Reference was made earlier to the three units currently in use to measure digestibility. They are highly correlated when measured *in vitro* on typical forages. The following equations have been derived from a statistical study of 134 sets of results from the Tilley and Terry method:

$$\text{DOMD } \% = 0.98 \text{ DMD } \% - 4.8 \tag{59}$$

$$\text{DOMD } \% = 0.92 \text{ OMD } \% - 1.2 \tag{60}$$

Equation (58) can be used on most *in vitro* DOMD values (IVD) of ruminant foods with the exception of high oil or fat containing foods and perhaps very high protein foods.

Where only OMD or DMD values are available, these should first be converted to DOMD values by the use of equations (55), (59) or (60).

Greater precision can be obtained by varying the coefficient according to the class of food as follows:

0.15 for hay, dried grass, straws.

0.16 for roots, leaves of roots, other green foods, grasses, legumes, miscellaneous, cereals and by-products.

3. Those that predict ME values from the chemical composition of the food. Equations for various forages are given below. They are based on analyses for crude fibre (CF), acid detergent fibre (ADF) or modified acid detergent fibre (MADF), and crude protein (CP) sometimes combined with the fibre. It is essential that the correct equation be used for the specified fibre. Alternatively *in vitro* DOMD content (IVD) is used.
*Equations are for analyses expressed as g/kg DM* except for IVD which is kept as a percentage.

*Fresh herbage*

*Grasses*

$$\text{General equation MEF} = 15.9 - 0.019 \text{ MADF} \qquad (61)$$
$$\text{Regrowths only MEF} = 16.6 - 0.022 \text{ MADF} \qquad (62)$$

*Legumes*

$$\text{MEF} = 12.3 - 0.012 \text{ MADF} \qquad (63)$$

(D. E. Morgan *Annual Report of ADAS Science Arm 1972* pp 98-101)

Workers at the Grassland Research Institute have recently proposed the following equation for grasses, clovers, legumes and maize:

$$\text{MEF} = 0.23 + 0.138 \text{ IVD} + 0.01 \text{ CP} \qquad (64)$$

*Grass hays*

$$\text{MEF} = 0.84 + 0.14 \text{ IVD} \qquad (65)$$
$$= 13.3 - 0.019 \text{ CF} + 0.017 \text{ CP} \qquad (66)$$
$$= 13.5 - 0.015 \text{ ADF} + 0.014 \text{ CP} \qquad (67)$$
$$= 17.1 - 0.022 \text{ MADF} \qquad (68)$$

(D. E. Morgan *Annual Report of ADAS Science Arm 1972*, p 98)

*Dried grass and legumes*

Dried grass is available in several forms depending on the type of drying plant. The physical form may be long, short chopped, wafered, pelleted or finely ground meal. Drying temperatures may be low (up to 250°C) or high (500 – 1,000°C).

Low temperature dried grass is usually in the long or chopped state and ME values can be predicted from equations (61) to (63) given under *Fresh herbage*.

Dried grass which has been wafered, ground and/or pelleted has to be treated separately. These processes reduce both the digestibility and metabolisable energy content (calculated as 0.81 × DE) of foods. However, the efficiency of utilisation of ME is increased to the extent that the net energy of ground pelleted dried grass is approximately equal to that of the original material from which it was prepared. This effect has been shown on average to be equivalent to an 8% depression of the ME value. Thus values determined from digestibility trials should be increased by a factor of 1.08 *and no allowance made for increased efficiency of utilisation in subsequent calculations*.

Provisional equations derived from a study of 20 dried grass samples are as follows:

$$\text{MEF} = 14.0 - 0.014 \text{ MADF} \qquad (69)$$
$$\text{MEF} = 13.9 - 0.017 \text{ CF} \qquad (70)$$

Work is in progress on this topic and improved equations should become available in due course.

*Grass silages*

The chemistry of the ensilage process is complex and can result in elevation of the energy value of the dry matter if secondary fermentation takes place.

ME values of silages depend not only on their fibre content but also on their protein and dry matter contents. The following may be used as provisional equations pending completion of further work on this subject:

General equation:

$$\text{MEF} = 10.9 + 0.021\ \text{CP} - 0.0047\ \text{MADF} - 0.006\ \text{DM} \qquad (71)$$

$$= 5.4 + 0.022\ \text{CP} + 0.06\ \text{IVD} - 0.006\ \text{DM} \qquad (72)$$

where CP is total N × 6.25 g/kg DM determined on fresh silage
MADF and DM are g/kg (10 × %)
IVD is *in vitro* DOMD %

Primary growth only:

$$\text{MEF} = 5.0 + 0.019\ \text{CP} + 0.07\ \text{IVD} - 0.005\ \text{DM} \qquad (73)$$

### *Maize silage*

No *in vivo* studies on maize silage have been made but use can be made of equation (58) if *in vitro* DOMD values are available. From a study of the relationship between *in vitro* DOMD values and MADF values, the following provisional equation is suggested:

$$\text{MEF} = 14.0 - 0.0131\ \text{MADF} - 0.003\ \text{DM} \qquad (74)$$

## ESTIMATION OF THE METABOLISABLE ENERGY VALUES OF COMPOUND FOODS

Equation (2) can be used to calculate MEF values of compounds if the digestible nutrients are known, as in the Food Tables. With compound foods, the only information normally available is the content of crude protein, oil and crude fibre, and digestibility coefficients are not known. It is suggested that the following typical digestibility coefficients should be assumed:

| | |
|---|---|
| Crude protein | 0.8 |
| Oil (ether extract) | 0.9 |
| Crude fibre | 0.4 |
| N free extract | 0.9 |

Equation (2) can then be restated as

$$\text{MEF} = 0.012\ \text{CP} + 0.031\ \text{EE} + 0.005\ \text{CF} + 0.014\ \text{NFE} \qquad (75)$$

where all analyses are in g/kg DM.

Since the crude fibre content of many compound foods is fairly low *in vitro* DOMD values can be used to verify the validity of the assumed digestibility coefficients suggested. Equation (58) can then be used to calculate an MEF value employing a coefficient of 0.16 (not 0.15).

## Tables of Food Composition

| | |
|---|---|
| 1 | Roots |
| 2 | Leaves of roots |
| 3 | Other green foods |
| 4 | Cereals |
| 5 | Grasses |
| 6 | Green legumes |
| 7 | Miscellaneous |
| 8a | Silage—clamp |
| 8b | Silage—tower |
| 9 | Hay |
| 10 | Dried grasses and legumes |
| 11 | Straws and chaff |
| 12a | Grains and Seeds—cereals |
| 12b | Legumes |
| 12c | Oil seeds |
| 12d | Miscellaneous seeds |
| 13 | Oil cakes and meals |
| 14 | Feedingstuffs of animal origin |
| 15 | By-products |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ kg DM | Q $\left\{\frac{ME}{GE}\right\}$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1 Roots** | | | | | | | | | | | | | | | | |
| 101 | Artichoke, Jerusalem | 200 | 13·2 | 50 | 75 | 10 | 35 | 825 | 55 | 17·4 | 0·76 | 84 | 0·67 | 0·00 | 0·29 | 0·94 | 101 |
| 102 | Carrots | 130 | 12·8 | 62 | 92 | 15 | 108 | 715 | 69 | 17·4 | 0·73 | 81 | 0·67 | 0·50 | 0·50 | 0·96 | 102 |
| 103 | Kohlrabi | 130 | 10·8 | 54 | 154 | 8 | 108 | 654 | 77 | 17·4 | 0·62 | 69 | 0·35 | 0·00 | 0·43 | 0·90 | 103 |
| 104 | Mangels, White-fleshed globe | 110 | 12·5 | 64 | 91 | 9 | 64 | 773 | 64 | 17·3 | 0·72 | 79 | 0·70 | 0·00 | 0·43 | 0·91 | 104 |
| 105 | Mangels, intermediate | 120 | 12·4 | 58 | 83 | 8 | 58 | 783 | 67 | 17·2 | 0·72 | 79 | 0·70 | 0·00 | 0·43 | 0·90 | 105 |
| 106 | Mangels, yellow-fleshed globe | 130 | 12·4 | 54 | 92 | 8 | 62 | 769 | 69 | 17·2 | 0·72 | 78 | 0·58 | 0·00 | 0·38 | 0·92 | 106 |
| 107 | Mangels, long red | 130 | 12·6 | 54 | 77 | 8 | 62 | 785 | 69 | 17·1 | 0·74 | 80 | 0·70 | 0·00 | 0·38 | 0·92 | 107 |
| 108 | Parsnips | 150 | 13·3 | 67 | 87 | 20 | 80 | 753 | 60 | 17·6 | 0·76 | 84 | 0·77 | 0·33 | 0·58 | 0·96 | 108 |
| 109 | Potatoes | 210 | 12·5 | 47 | 90 | 5 | 38 | 824 | 43 | 17·6 | 0·71 | 79 | 0·52 | 0·00 | 0·00 | 0·90 | 109 |
| 110 | Sugar beet | 230 | 13·7 | 35 | 48 | 4 | 48 | 870 | 30 | 17·6 | 0·78 | 87 | 0·73 | 0·00 | 0·36 | 0·94 | 110 |
| 111 | Swede Turnip | 120 | 12·8 | 91 | 108 | 17 | 100 | 717 | 58 | 17·7 | 0·72 | 82 | 0·84 | 0·00 | 0·66 | 0·93 | 111 |
| 112 | Turnip | 90 | 11·2 | 73 | 122 | 22 | 111 | 667 | 78 | 17·6 | 0·64 | 72 | 0·60 | 0·00 | 0·33 | 0·91 | 112 |
| | **2 Leaves of roots** | | | | | | | | | | | | | | | | |
| 201 | Artichoke tops | 320 | 8·8 | 65 | 106 | 34 | 169 | 534 | 156 | 16·5 | 0·53 | 55 | 0·61 | 0·45 | 0·41 | 0·75 | 201 |
| 202 | Carrot leaves | 180 | 7·9 | 123 | 189 | 50 | 133 | 389 | 239 | 15·7 | 0·50 | 48 | 0·65 | 0·56 | 0·56 | 0·66 | 202 |
| 203 | Kohlrabi leaves | 140 | 10·2 | 141 | 207 | 29 | 121 | 529 | 114 | 17·5 | 0·58 | 65 | 0·68 | 0·50 | 0·56 | 0·80 | 203 |
| 204 | Mangel leaves | 110 | 9·0 | 146 | 218 | 36 | 145 | 418 | 182 | 16·6 | 0·54 | 57 | 0·67 | 0·50 | 0·57 | 0·76 | 204 |
| 205 | Potato haulm | 230 | 6·5 | 48 | 109 | 43 | 270 | 443 | 135 | 17·3 | 0·38 | 42 | 0·44 | 0·20 | 0·36 | 0·60 | 205 |
| 206 | Sugar beet tops | 160 | 9·9 | 88 | 125 | 31 | 100 | 531 | 212 | 15·4 | 0·64 | 62 | 0·70 | 0·60 | 0·69 | 0·83 | 206 |
| 207 | Turnip leaves | 120 | 9·2 | 130 | 192 | 42 | 125 | 458 | 183 | 16·5 | 0·55 | 58 | 0·68 | 0·40 | 0·53 | 0·79 | 207 |
| | **3 Other green foods** | | | | | | | | | | | | | | | | |
| 301 | Cabbage, drumhead | 110 | 10·4 | 100 | 136 | 36 | 182 | 536 | 109 | 17·5 | 0·59 | 66 | 0·73 | 0·50 | 0·70 | 0·78 | 301 |
| 302 | Cabbage, open leaved | 150 | 10·8 | 115 | 160 | 47 | 160 | 527 | 107 | 17·9 | 0·60 | 68 | 0·72 | 0·57 | 0·71 | 0·80 | 302 |
| 303 | Comfrey | 120 | 8·5 | 130 | 217 | 25 | 150 | 433 | 175 | 16·5 | 0·52 | 54 | 0·60 | 0·67 | 0·47 | 0·74 | 303 |
| 304 | Kale, thousandhead | 160 | 11·1 | 106 | 137 | 25 | 200 | 531 | 106 | 17·4 | 0·64 | 71 | 0·77 | 0·50 | 0·56 | 0·90 | 304 |
| 305 | Kale, marrow stem (unthinned) | 140 | 11·0 | 123 | 157 | 36 | 179 | 493 | 136 | 17·2 | 0·64 | 69 | 0·78 | 0·60 | 0·64 | 0·88 | 305 |
| 306 | Kale, marrow stem (singled) | 140 | 11·0 | 114 | 150 | 21 | 179 | 521 | 129 | 16·9 | 0·65 | 70 | 0·76 | 0·67 | 0·60 | 0·89 | 306 |
| 307 | Broccoli, purple sprouting | 120 | 11·1 | 117 | 158 | 25 | 125 | 592 | 100 | 17·5 | 0·63 | 70 | 0·74 | 0·67 | 0·74 | 0·80 | 307 |
| 308 | Mustard | 150 | 9·0 | 126 | 193 | 27 | 193 | 493 | 93 | 17·9 | 0·50 | 57 | 0·65 | 0·50 | 0·52 | 0·68 | 308 |
| 309 | Rape | 140 | 9·5 | 144 | 200 | 57 | 250 | 400 | 93 | 18·7 | 0·51 | 59 | 0·72 | 0·63 | 0·54 | 0·68 | 309 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg | | | | | Gross Energy MJ/kg DM | Q $\left(\frac{ME}{GE}\right)$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal) | | | | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | |
| | **4 Cereals** | | | | | | | | | | | | | | | | |
| 401 | Barley in flower | 250 | 10·0 | 46 | 68 | 16 | 316 | 536 | 64 | 17·7 | 0·56 | 66 | 0·68 | 0·60 | 0·64 | 0·75 | 401 |
| 402 | Maize | 190 | 8·8 | 53 | 89 | 26 | 289 | 532 | 63 | 18·1 | 0·49 | 57 | 0·59 | 0·60 | 0·55 | 0·64 | 402 |
| 403 | Millet | 130 | 7·9 | 54 | 100 | 15 | 315 | 477 | 92 | 17·4 | 0·45 | 52 | 0·54 | 0·50 | 0·54 | 0·61 | 403 |
| 404 | Oats in flower | 230 | 8·6 | 61 | 83 | 26 | 365 | 448 | 78 | 17·9 | 0·48 | 57 | 0·74 | 0·66 | 0·58 | 0·62 | 404 |
| 405 | Rye in flower | 230 | 9·5 | 88 | 126 | 39 | 322 | 439 | 74 | 18·4 | 0·52 | 62 | 0·70 | 0·56 | 0·65 | 0·68 | 405 |
| | **5 Grasses** | | | | | | | | | | | | | | | | |
| 501 | Pasture grass, close grazing; Non-rotational | 200 | 12·1 | 225 | 265 | 55 | 130 | 445 | 105 | 18·6 | 0·65 | 75 | 0·85 | 0·64 | 0·81 | 0·87 | 501 |
| 502 | Rotational, with 3 weekly intervals | 200 | 12·1 | 185 | 225 | 65 | 155 | 465 | 90 | 18·9 | 0·64 | 75 | 0·82 | 0·61 | 0·81 | 0·86 | 502 |
| 503 | Rotational, with monthly intervals | 200 | 11·2 | 130 | 175 | 50 | 225 | 460 | 90 | 18·5 | 0·61 | 72 | 0·74 | 0·50 | 0·82 | 0·82 | 503 |
| 504 | Pasture grass, extensive grazing Spring value, running off during summer | 200 | 10·0 | 124 | 175 | 40 | 200 | 485 | 100 | 18·0 | 0·56 | 64 | 0·71 | 0·50 | 0·65 | 0·75 | 504 |
| 505 | Winter pasturage (after close grazing allowing free growth from end July to December) | 200 | 9·7 | 101 | 155 | 30 | 220 | 515 | 80 | 18·1 | 0·53 | 63 | 0·65 | 0·16 | 0·59 | 0·77 | 505 |
| 506 | Rice grass | 220 | 7·0 | 59 | 132 | 27 | 227 | 505 | 109 | 17·4 | 0·40 | 46 | 0·45 | 0·50 | 0·66 | 0·46 | 506 |
| 507 | Ryegrass perennial post flowering | 250 | 8·4 | 72 | 116 | 28 | 288 | 464 | 104 | 17·5 | 0·48 | 55 | 0·62 | 0·43 | 0·56 | 0·65 | 507 |
| 508 | Ryegrass, Italian post flowering | 250 | 8·7 | 84 | 136 | 40 | 248 | 464 | 112 | 17·7 | 0·49 | 55 | 0·62 | 0·50 | 0·58 | 0·66 | 508 |
| 509 | Sorghum | 200 | 8·0 | 60 | 105 | 30 | 310 | 485 | 70 | 18·1 | 0·44 | 53 | 0·57 | 0·33 | 0·53 | 0·60 | 509 |
| 510 | Timothy, in flower | 250 | 8·5 | 52 | 96 | 32 | 280 | 524 | 68 | 18·1 | 0·47 | 55 | 0·54 | 0·50 | 0·53 | 0·63 | 510 |
| | **6 Green legumes** | | | | | | | | | | | | | | | | |
| 601 | Alsike | 150 | 8·8 | 141 | 220 | 40 | 300 | 340 | 100 | 18·4 | 0·48 | 56 | 0·64 | 0·67 | 0·49 | 0·71 | 601 |
| 602 | Crimson Clover | 190 | 9·5 | 114 | 153 | 37 | 337 | 374 | 100 | 18·0 | 0·53 | 61 | 0·75 | 0·71 | 0·57 | 0·75 | 602 |
| 603 | Red Clover, beginning to flower | 190 | 10·2 | 132 | 179 | 37 | 274 | 426 | 84 | 18·3 | 0·56 | 65 | 0·74 | 0·71 | 0·58 | 0·78 | 603 |
| 604 | White Clover, beginning to flower | 190 | 9·0 | 152 | 237 | 42 | 232 | 374 | 116 | 18·1 | 0·50 | 57 | 0·64 | 0·63 | 0·60 | 0·68 | 604 |
| 605 | Beans, beginning to flower | 150 | 9·2 | 154 | 213 | 53 | 220 | 380 | 133 | 17·9 | 0·51 | 57 | 0·72 | 0·62 | 0·49 | 0·72 | 605 |
| 606 | Kidney Vetch | 180 | 8·7 | 77 | 133 | 33 | 283 | 478 | 72 | 18·3 | 0·48 | 56 | 0·58 | 0·50 | 0·53 | 0·66 | 606 |
| 607 | Lucerne, early flower | 240 | 8·2 | 130 | 171 | 17 | 300 | 413 | 100 | 17·6 | 0·47 | 54 | 0·76 | 0·25 | 0·44 | 0·67 | 607 |
| 608 | Lucerne, in bud | 220 | 9·4 | 164 | 205 | 23 | 282 | 409 | 82 | 18·2 | 0·52 | 62 | 0·80 | 0·20 | 0·50 | 0·76 | 608 |
| 609 | Lucerne, before bud | 150 | 10·2 | 213 | 253 | 27 | 220 | 380 | 120 | 17·8 | 0·57 | 67 | 0·84 | 0·25 | 0·64 | 0·81 | 609 |
| 610 | Peas, beginning to flower | 170 | 8·5 | 140 | 206 | 35 | 353 | 335 | 71 | 18·8 | 0·45 | 56 | 0·68 | 0·50 | 0·50 | 0·66 | 610 |
| 611 | Sainfoin, early flower | 230 | 10·3 | 143 | 196 | 26 | 209 | 509 | 61 | 18·5 | 0·56 | 65 | 0·73 | 0·67 | 0·45 | 0·78 | 611 |
| 612 | Sainfoin, full flower | 250 | 8·4 | 116 | 176 | 24 | 236 | 500 | 64 | 18·3 | 0·46 | 54 | 0·66 | 0·50 | 0·46 | 0·61 | 612 |
| 613 | Trefoil | 200 | 9·0 | 121 | 175 | 40 | 285 | 420 | 80 | 18·5 | 0·49 | 57 | 0·69 | 0·50 | 0·49 | 0·70 | 613 |
| 614 | Vetches, in flower | 180 | 8·6 | 123 | 178 | 28 | 294 | 417 | 83 | 18·2 | 0·48 | 56 | 0·69 | 0·60 | 0·45 | 0·68 | 614 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q (ME/GE) | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **7 Miscellaneous** | | | | | | | | | | | | | | | | |
| 701 | Brushwood | 750 | 6·3 | 28 | 61 | 25 | 356 | 537 | 20 | 18·8 | 0·34 | 41 | 0·46 | 0·42 | 0·28 | 0·50 | 701 |
| 702 | Buckwheat | 160 | 9·1 | 100 | 156 | 38 | 262 | 475 | 69 | 18·5 | 0·49 | 59 | 0·64 | 0·50 | 0·57 | 0·67 | 702 |
| 703 | Gorse | 500 | 6·8 | 44 | 104 | 22 | 468 | 352 | 54 | 18·5 | 0·37 | 45 | 0·42 | 0·45 | 0·40 | 0·60 | 703 |
| 704 | Heather | 500 | 6·0 | 28 | 70 | 86 | 454 | 332 | 58 | 19·7 | 0·31 | 37 | 0·40 | 0·35 | 0·31 | 0·52 | 704 |
| 705 | Artichoke tops (dried) | 870 | 8·5 | 87 | 145 | 25 | 162 | 551 | 117 | 17·2 | 0·49 | 53 | 0·60 | 0·50 | 0·29 | 0·70 | 705 |
| 706 | Elm leaves (dried) | 880 | 10·3 | 132 | 181 | 33 | 98 | 567 | 122 | 17·3 | 0·59 | 65 | 0·73 | 0·24 | 0·57 | 0·81 | 706 |
| 707 | Hop leaves and bine (dried) | 890 | 8·2 | 90 | 140 | 39 | 273 | 426 | 121 | 17·6 | 0·47 | 51 | 0·64 | 0·72 | 0·31 | 0·71 | 707 |
| 708 | Leaves of trees in July (dried) | 840 | 9·1 | 74 | 125 | 36 | 169 | 587 | 83 | 17·9 | 0·51 | 55 | 0·59 | 0·80 | 0·37 | 0·66 | 708 |
| 709 | Nettles (dried) | 890 | 10·4 | 145 | 207 | 87 | 119 | 429 | 158 | 18·1 | 0·57 | 61 | 0·70 | 0·64 | 0·57 | 0·79 | 709 |
| 710 | Poplar leaves in October (dried) | 840 | 9·7 | 72 | 129 | 104 | 207 | 471 | 89 | 19·4 | 0·50 | 53 | 0·56 | 0·79 | 0·32 | 0·66 | 710 |
| | **8a Silage—Clamp** | | | | | | | | | | | | | | | | |
| 801 | Alsike | 250 | 8·6 | 80 | 136 | 72 | 272 | 436 | 84 | 18·9 | 0·45 | 51 | 0·59 | 0·67 | 0·50 | 0·57 | 801 |
| 802 | Clover (Red) | 220 | 8·8 | 135 | 205 | 55 | 300 | 327 | 114 | 18·4 | 0·48 | 56 | 0·66 | 0·54 | 0·53 | 0·72 | 802 |
| 803 | Grass (very high digestibility) | 200 | 10·2 | 116 | 170 | 40 | 300 | 390 | 100 | 18·1 | 0·57 | 67 | 0·68 | 0·67 | 0·81 | 0·72 | 803 |
| 804 | Grass (high digestibility) | 200 | 9·3 | 107 | 170 | 40 | 305 | 390 | 95 | 18·2 | 0·51 | 61 | 0·63 | 0·62 | 0·76 | 0·63 | 804 |
| 805 | Grass (moderate digestibility) | 200 | 8·8 | 102 | 160 | 35 | 340 | 375 | 90 | 18·2 | 0·48 | 58 | 0·64 | 0·57 | 0·73 | 0·56 | 805 |
| 806 | Grass (low digestibility) | 200 | 7·6 | 98 | 160 | 35 | 380 | 345 | 80 | 18·4 | 0·41 | 52 | 0·61 | 0·35 | 0·69 | 0·42 | 806 |
| 807 | Lucerne | 250 | 8·5 | 113 | 168 | 84 | 296 | 352 | 100 | 19·1 | 0·45 | 52 | 0·67 | 0·48 | 0·42 | 0·69 | 807 |
| 808 | Maize | 210 | 10·8 | 70 | 110 | 57 | 233 | 538 | 62 | 18·8 | 0·57 | 65 | 0·64 | 0·90 | 0·68 | 0·69 | 808 |
| 809 | Mangel leaves | 220 | 6·9 | 88 | 132 | 50 | 145 | 450 | 223 | 15·8 | 0·44 | 43 | 0·67 | 0·40 | 0·55 | 0·54 | 809 |
| 810 | Marrowstem kale | 160 | 9·8 | 95 | 125 | 31 | 231 | 456 | 156 | 16·6 | 0·59 | 65 | 0·76 | 0·00 | 0·74 | 0·85 | 810 |
| 811 | Mustard | 150 | 9·6 | 107 | 167 | 27 | 253 | 400 | 153 | 16·8 | 0·57 | 60 | 0·64 | 1·00 | 0·50 | 0·85 | 811 |
| 812 | Oats (green) | 240 | 8·0 | 47 | 79 | 33 | 358 | 454 | 75 | 18·1 | 0·44 | 53 | 0·60 | 0·50 | 0·60 | 0·55 | 812 |
| 813 | Overheated ryegrass and clover | 320 | 7·1 | 16 | 134 | 34 | 319 | 422 | 91 | 18·0 | 0·39 | 45 | 0·12 | 0·73 | 0·55 | 0·56 | 813 |
| 814 | Pea Haulm & Pods (Canning) | 210 | 8·7 | 95 | 167 | 67 | 290 | 276 | 200 | 16·9 | 0·51 | 51 | 0·57 | 0·93 | 0·56 | 0·69 | 814 |
| 815 | Pea Pods (canning) | 280 | 10·6 | 85 | 129 | 36 | 307 | 464 | 64 | 18·5 | 0·58 | 67 | 0·66 | 0·90 | 0·65 | 0·77 | 815 |
| 816 | Potatoes | 270 | 11·8 | 39 | 81 | 19 | 26 | 822 | 52 | 17·6 | 0·67 | 74 | 0·48 | 0·20 | 0·00 | 0·85 | 816 |
| 817 | Potato Haulm | 250 | 6·4 | 49 | 128 | 108 | 176 | 364 | 224 | 17·1 | 0·38 | 36 | 0·38 | 0·44 | 0·39 | 0·55 | 817 |
| 818 | Rye | 130 | 8·3 | 71 | 123 | 38 | 338 | 431 | 69 | 18·5 | 0·45 | 55 | 0·58 | 0·38 | 0·60 | 0·60 | 818 |
| 819 | Sainfoin | 240 | 8·4 | 124 | 179 | 63 | 333 | 342 | 83 | 19·0 | 0·44 | 52 | 0·69 | 0·50 | 0·42 | 0·67 | 819 |
| 820 | Sugar beet pulp (wet) | 120 | 9·7 | 42 | 83 | 17 | 200 | 625 | 75 | 17·5 | 0·55 | 62 | 0·50 | 0·50 | 0·50 | 0·75 | 820 |
| 821 | Sugar beet tops | 230 | 7·9 | 65 | 104 | 30 | 148 | 396 | 322 | 13·4 | 0·59 | 50 | 0·62 | 0·50 | 0·73 | 0·80 | 821 |
| 822 | Sugar beet tops and pulp | 160 | 11·3 | 100 | 150 | 38 | 131 | 556 | 125 | 17·3 | 0·65 | 70 | 0·67 | 0·67 | 0·81 | 0·85 | 822 |
| 823 | Sunflowers | 220 | 8·4 | 51 | 95 | 45 | 305 | 450 | 105 | 17·8 | 0·47 | 53 | 0·53 | 0·67 | 0·49 | 0·66 | 823 |
| 824 | Turnip tops | 170 | 8·4 | 88 | 124 | 35 | 159 | 353 | 329 | 13·5 | 0·62 | 52 | 0·71 | 0·83 | 0·68 | 0·83 | 824 |
| 825 | Vetch and oats | 270 | 9·6 | 82 | 126 | 44 | 293 | 456 | 81 | 18·3 | 0·52 | 60 | 0·65 | 0·73 | 0·58 | 0·70 | 825 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q $\left\{\frac{ME}{GE}\right\}$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **8b Silage—Tower** | | | | | | | | | | | | | | | | |
| 826 | Barley (whole crop) | 400 | 9·6 | 50 | 95 | 22 | 250 | 570 | 63 | 18·0 | 0·54 | 62 | 0·53 | 0·61 | 0·53 | 0·74 | 826 |
| 827 | Grass (very high digestibility) | 400 | 10·4 | 121 | 170 | 38 | 313 | 383 | 97 | 18·1 | 0·57 | 68 | 0·71 | 0·65 | 0·80 | 0·74 | 827 |
| 828 | Grass (high digestibility) | 400 | 9·3 | 87 | 142 | 28 | 313 | 433 | 85 | 18·0 | 0·52 | 61 | 0·61 | 0·67 | 0·73 | 0·64 | 828 |
| 829 | Wheat (whole crop) | 400 | 8·4 | 36 | 78 | 17 | 300 | 563 | 42 | 18·2 | 0·46 | 55 | 0·47 | 0·56 | 0·43 | 0·66 | 829 |
| | **9 Hay** | | | | | | | | | | | | | | | | |
| 901 | Barley (just past milk stage) | 850 | 8·8 | 54 | 81 | 22 | 289 | 533 | 74 | 17·7 | 0·50 | 58 | 0·67 | 0·42 | 0·62 | 0·63 | 901 |
| 902 | Clover, crimson | 850 | 8·2 | 100 | 144 | 29 | 314 | 426 | 87 | 18·0 | 0·46 | 54 | 0·70 | 0·40 | 0·47 | 0·65 | 902 |
| 903 | Clover, red very good | 850 | 9·6 | 128 | 184 | 39 | 266 | 428 | 84 | 18·4 | 0·52 | 61 | 0·70 | 0·64 | 0·50 | 0·75 | 903 |
| 904 | Clover, red good | 850 | 8·9 | 103 | 161 | 35 | 287 | 445 | 72 | 18·5 | 0·48 | 57 | 0·64 | 0·57 | 0·47 | 0·70 | 904 |
| 905 | Clover, red poor | 850 | 7·8 | 67 | 131 | 25 | 340 | 445 | 60 | 18·4 | 0·42 | 50 | 0·51 | 0·48 | 0·40 | 0·65 | 905 |
| 906 | Clover, red damaged | 850 | 6·9 | 73 | 141 | 18 | 394 | 364 | 84 | 17·9 | 0·38 | 46 | 0·52 | 0·47 | 0·40 | 0·60 | 906 |
| 907 | Grass (very high digestibility) | 850 | 10·1 | 90 | 132 | 20 | 291 | 473 | 85 | 17·7 | 0·57 | 67 | 0·68 | 0·37 | 0·76 | 0·75 | 907 |
| 908 | Grass (high digestibility) | 850 | 9·0 | 58 | 101 | 16 | 320 | 480 | 82 | 17·6 | 0·51 | 61 | 0·57 | 0·30 | 0·70 | 0·67 | 908 |
| 909 | Grass (moderate digestibility) | 850 | 8·4 | 39 | 85 | 16 | 328 | 496 | 74 | 17·7 | 0·48 | 57 | 0·46 | 0·27 | 0·61 | 0·65 | 909 |
| 910 | Grass (low digestibility) | 850 | 7·5 | 45 | 92 | 16 | 366 | 456 | 69 | 17·8 | 0·42 | 51 | 0·49 | 0·27 | 0·56 | 0·56 | 910 |
| 911 | Grass (very low digestibility) | 850 | 7·0 | 38 | 88 | 16 | 340 | 478 | 78 | 17·6 | 0·40 | 47 | 0·43 | 0·35 | 0·54 | 0·51 | 911 |
| 912 | Lucerne, before flowering | 850 | 8·3 | 143 | 193 | 28 | 321 | 371 | 87 | 18·2 | 0·46 | 54 | 0·74 | 0·46 | 0·42 | 0·68 | 912 |
| 913 | Lucerne, half flower | 850 | 8·2 | 166 | 225 | 13 | 302 | 365 | 95 | 17·9 | 0·46 | 55 | 0·74 | 0·00 | 0·48 | 0·66 | 913 |
| 914 | Lucerne, full flower | 850 | 7·7 | 116 | 171 | 31 | 353 | 349 | 96 | 18·1 | 0·43 | 51 | 0·68 | 0·46 | 0·45 | 0·62 | 914 |
| 915 | Millet hay | 850 | 8·4 | 71 | 125 | 26 | 339 | 445 | 66 | 18·2 | 0·46 | 56 | 0·57 | 0·41 | 0·60 | 0·61 | 915 |
| 916 | Mineral deficient hay (mainly purple molinia and brown bent) | 850 | 6·4 | 63 | 129 | 22 | 344 | 469 | 35 | 18·7 | 0·34 | 44 | 0·49 | 0·11 | 0·55 | 0·39 | 916 |
| 917 | Oats, milk stage | 850 | 7·8 | 52 | 94 | 31 | 324 | 473 | 79 | 18·0 | 0·43 | 50 | 0·55 | 0·62 | 0·52 | 0·56 | 917 |
| 918 | Rice grass, poor | 850 | 7·0 | 31 | 79 | 16 | 306 | 499 | 100 | 17·2 | 0·41 | 47 | 0·39 | 0·36 | 0·63 | 0·49 | 918 |
| 919 | Rye, before flowering | 850 | 9·5 | 85 | 121 | 29 | 332 | 455 | 62 | 18·4 | 0·52 | 62 | 0·70 | 0·60 | 0·60 | 0·70 | 919 |
| 920 | Sainfoin, before flowering | 850 | 9·2 | 129 | 182 | 38 | 296 | 404 | 80 | 18·5 | 0·50 | 58 | 0·71 | 0·66 | 0·43 | 0·74 | 920 |
| 921 | Sainfoin, in flower | 850 | 9·0 | 115 | 158 | 31 | 335 | 389 | 87 | 18·1 | 0·50 | 58 | 0·73 | 0·62 | 0·42 | 0·78 | 921 |
| 922 | Trefoil | 850 | 8·8 | 139 | 184 | 40 | 292 | 395 | 89 | 18·4 | 0·48 | 56 | 0·76 | 0·47 | 0·44 | 0·70 | 922 |
| 923 | Vetches, beginning to flower | 850 | 8·8 | 181 | 238 | 27 | 281 | 342 | 112 | 17·9 | 0·49 | 57 | 0·76 | 0·61 | 0·54 | 0·65 | 923 |
| 924 | Vetches, full flower | 850 | 8·0 | 113 | 171 | 29 | 306 | 394 | 100 | 17·9 | 0·45 | 52 | 0·66 | 0·60 | 0·50 | 0·60 | 924 |
| 925 | Vetches, and oats (vetches in flower) | 850 | 8·1 | 77 | 138 | 39 | 288 | 433 | 102 | 17·9 | 0·46 | 52 | 0·56 | 0·52 | 0·51 | 0·64 | 925 |
| 926 | Wheat, milk stage | 850 | 8·5 | 36 | 66 | 19 | 293 | 551 | 72 | 17·6 | 0·48 | 56 | 0·55 | 0·56 | 0·58 | 0·62 | 926 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q (ME/GE) | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **10 Dried Grasses and Legumes** | | | | | | | | | | | | | | | | |
| 1001 | Grass, very leafy | 900 | 10·8 | 113 | 161 | 28 | 217 | 471 | 123 | 17·3 | 0·62 | 70 | 0·70 | 0·58 | 0·83 | 0·83 | 1001 |
| 1002 | Grass, leafy | 900 | 10·6 | 136 | 187 | 38 | 213 | 460 | 102 | 18·0 | 0·59 | 68 | 0·73 | 0·61 | 0·79 | 0·77 | 1002 |
| 1003 | Grass, early flower | 900 | 9·7 | 97 | 154 | 28 | 258 | 453 | 107 | 17·6 | 0·55 | 64 | 0·63 | 0·49 | 0·75 | 0·73 | 1003 |
| 1004 | Lucerne, just in bud | 900 | 9·4 | 174 | 244 | 32 | 198 | 400 | 126 | 17·7 | 0·53 | 60 | 0·71 | 0·45 | 0·53 | 0·78 | 1004 |
| 1005 | Lucerne, early flower | 900 | 8·7 | 128 | 178 | 27 | 269 | 414 | 112 | 17·6 | 0·49 | 57 | 0·72 | 0·29 | 0·46 | 0·74 | 1005 |
| 1006 | Lucerne leaf meal (Amer.) | 900 | 9·3 | 179 | 236 | 21 | 176 | 446 | 122 | 17·4 | 0·54 | 61 | 0·76 | 0·00 | 0·49 | 0·78 | 1006 |
| | **11 Straws and chaff** | | | | | | | | | | | | | | | | |
| 1101 | Barley straw, Spring | 860 | 7·3 | 9 | 38 | 21 | 394 | 493 | 53 | 18·0 | 0·40 | 49 | 0·24 | 0·33 | 0·54 | 0·53 | 1101 |
| 1102 | Barley straw, Winter | 860 | 5·8 | 8 | 37 | 16 | 488 | 392 | 66 | 17·8 | 0·32 | 39 | 0·22 | 0·29 | 0·38 | 0·50 | 1102 |
| 1103 | Bean straw (including pods) | 860 | 7·4 | 26 | 52 | 9 | 501 | 384 | 53 | 18·0 | 0·41 | 50 | 0·49 | 0·63 | 0·43 | 0·67 | 1103 |
| 1104 | Buckwheat straw | 860 | 6·6 | 27 | 57 | 14 | 455 | 413 | 62 | 17·9 | 0·37 | 45 | 0·47 | 0·42 | 0·45 | 0·52 | 1104 |
| 1105 | Clover straw, red | 840 | 5·6 | 48 | 108 | 21 | 531 | 271 | 68 | 18·3 | 0·31 | 38 | 0·44 | 0·33 | 0·37 | 0·49 | 1105 |
| 1106 | Maize straw | 850 | 7·3 | 20 | 59 | 18 | 461 | 406 | 56 | 18·1 | 0·40 | 51 | 0·34 | 0·33 | 0·60 | 0·50 | 1106 |
| 1107 | Oat straw, Spring | 860 | 6·7 | 11 | 34 | 22 | 394 | 493 | 57 | 18·0 | 0·38 | 46 | 0·34 | 0·32 | 0·54 | 0·46 | 1107 |
| 1108 | Oat straw, Winter | 860 | 6·8 | 9 | 22 | 17 | 402 | 501 | 57 | 17·8 | 0·38 | 46 | 0·40 | 0·33 | 0·57 | 0·44 | 1108 |
| 1109 | Pea straw | 860 | 6·5 | 50 | 105 | 19 | 410 | 390 | 77 | 17·9 | 0·36 | 43 | 0·48 | 0·44 | 0·39 | 0·55 | 1109 |
| 1110 | Rape straw | 840 | 6·5 | 21 | 30 | 14 | 450 | 461 | 45 | 18·0 | 0·36 | 44 | 0·72 | 0·42 | 0·37 | 0·53 | 1110 |
| 1111 | Rye straw, Spring | 860 | 6·2 | 7 | 37 | 19 | 429 | 485 | 30 | 18·4 | 0·33 | 42 | 0·19 | 0·50 | 0·47 | 0·41 | 1111 |
| 1112 | Rye straw, Winter | 860 | 6·3 | 7 | 36 | 16 | 465 | 437 | 45 | 18·1 | 0·35 | 43 | 0·19 | 0·50 | 0·51 | 0·41 | 1112 |
| 1113 | Soya bean straw | 840 | 7·5 | 44 | 88 | 24 | 311 | 456 | 121 | 17·0 | 0·44 | 48 | 0·50 | 0·60 | 0·38 | 0·66 | 1113 |
| 1114 | Tare or Vetch straw | 860 | 6·3 | 48 | 105 | 20 | 472 | 342 | 62 | 18·3 | 0·34 | 42 | 0·46 | 0·47 | 0·40 | 0·52 | 1114 |
| 1115 | Wheat straw, Spring | 860 | 5·6 | 1 | 34 | 15 | 417 | 463 | 71 | 17·6 | 0·32 | 39 | 0·03 | 0·31 | 0·50 | 0·37 | 1115 |
| 1116 | Wheat straw, Winter | 860 | 5·7 | 1 | 24 | 15 | 426 | 473 | 62 | 17·7 | 0·32 | 39 | 0·03 | 0·31 | 0·50 | 0·37 | 1116 |
| 1117 | Linseed chaff | 880 | 5·0 | 16 | 40 | 39 | 460 | 395 | 66 | 18·3 | 0·27 | 32 | 0·40 | 0·50 | 0·30 | 0·37 | 1117 |
| 1118 | Lupin pods | 870 | 7·4 | 39 | 103 | 8 | 334 | 485 | 69 | 17·7 | 0·42 | 50 | 0·38 | 0·29 | 0·48 | 0·61 | 1118 |
| 1119 | Millet chaff and husks | 880 | 5·2 | 19 | 55 | 25 | 464 | 330 | 127 | 17·0 | 0·31 | 35 | 0·35 | 0·32 | 0·37 | 0·47 | 1119 |
| 1120 | Oat chaff, Spring | 860 | 6·4 | 26 | 70 | 24 | 265 | 521 | 120 | 16·9 | 0·38 | 41 | 0·37 | 0·48 | 0·45 | 0·49 | 1120 |
| 1121 | Rice husks | 900 | 2·5 | 5 | 42 | 16 | 421 | 364 | 157 | 16·1 | 0·15 | 15 | 0·11 | 0·64 | 0·01 | 0·35 | 1121 |
| 1122 | Rye chaff | 860 | 5·8 | 13 | 41 | 15 | 515 | 340 | 90 | 17·4 | 0·33 | 41 | 0·31 | 0·31 | 0·50 | 0·39 | 1122 |
| 1123 | Soya bean pods | 890 | 8·6 | 30 | 67 | 17 | 340 | 482 | 93 | 17·3 | 0·50 | 56 | 0·44 | 0·53 | 0·51 | 0·73 | 1123 |
| 1124 | Wheat chaff | 860 | 5·9 | 13 | 43 | 14 | 322 | 495 | 126 | 16·5 | 0·36 | 39 | 0·30 | 0·29 | 0·48 | 0·45 | 1124 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q $\left(\frac{ME}{GE}\right)$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **12a Grains and seeds—cereals** | | | | | | | | | | | | | | | | |
| 1201 | Barley | 860 | 13·7 | 82 | 108 | 17 | 53 | 795 | 26 | 18·3 | 0·75 | 86 | 0·76 | 0·80 | 0·56 | 0·92 | 1201 |
| 1202 | Sorghum | 860 | 13·4 | 87 | 108 | 43 | 21 | 801 | 27 | 18·8 | 0·72 | 81 | 0·80 | 0·79 | 0·53 | 0·85 | 1202 |
| 1203 | Maize | 860 | 14·2 | 78 | 98 | 42 | 24 | 823 | 13 | 19·0 | 0·75 | 87 | 0·80 | 0·61 | 0·36 | 0·92 | 1203 |
| 1204 | Millet | 860 | 11·3 | 92 | 121 | 44 | 93 | 698 | 44 | 18·7 | 0·61 | 68 | 0·76 | 0·80 | 0·33 | 0·75 | 1204 |
| 1205 | Oats | 860 | 11·5 | 84 | 109 | 49 | 121 | 688 | 33 | 19·0 | 0·61 | 68 | 0·77 | 0·83 | 0·25 | 0·77 | 1205 |
| 1206 | Rice (polished) | 860 | 15·0 | 67 | 77 | 5 | 17 | 892 | 9 | 18·0 | 0·83 | 94 | 0·87 | 0·50 | 0·47 | 0·97 | 1206 |
| 1207 | Rye | 860 | 14·0 | 110 | 133 | 20 | 22 | 802 | 23 | 18·4 | 0·76 | 87 | 0·83 | 0·65 | 0·53 | 0·92 | 1207 |
| 1208 | Wheat | 860 | 14·0 | 105 | 124 | 19 | 26 | 810 | 21 | 18·4 | 0·76 | 87 | 0·84 | 0·63 | 0·47 | 0·92 | 1208 |
| | **12b Legumes** | | | | | | | | | | | | | | | | |
| 1209 | Beans, field spring | 860 | 12·8 | 248 | 314 | 15 | 80 | 551 | 40 | 19·0 | 0·67 | 81 | 0·79 | 0·80 | 0·58 | 0·91 | 1209 |
| 1210 | Beans, field winter | 860 | 12·8 | 209 | 265 | 15 | 90 | 591 | 40 | 18·8 | 0·68 | 81 | 0·79 | 0·80 | 0·58 | 0·91 | 1210 |
| 1211 | Beans, butter | 860 | 12·6 | 175 | 265 | 13 | 42 | 631 | 49 | 18·5 | 0·68 | 80 | 0·66 | 0·64 | 0·62 | 0·93 | 1211 |
| 1212 | Gram | 860 | 12·4 | 173 | 263 | 13 | 57 | 610 | 57 | 18·4 | 0·67 | 78 | 0·66 | 0·64 | 0·57 | 0·93 | 1212 |
| 1213 | Lentils | 860 | 13·6 | 255 | 297 | 22 | 40 | 607 | 35 | 19·1 | 0·71 | 85 | 0·86 | 0·63 | 0·53 | 0·93 | 1213 |
| 1214 | Lupins, sweet (yellow) | 860 | 13·2 | 432 | 480 | 63 | 120 | 285 | 52 | 20·8 | 0·64 | 81 | 0·90 | 0·84 | 0·91 | 0·76 | 1214 |
| 1215 | Lupins, sweet (blue) | 860 | 13·3 | 346 | 388 | 67 | 83 | 423 | 38 | 20·6 | 0·65 | 81 | 0·89 | 0·81 | 0·97 | 0·77 | 1215 |
| 1216 | Peas | 860 | 13·4 | 225 | 262 | 19 | 63 | 624 | 33 | 18·9 | 0·71 | 85 | 0·86 | 0·63 | 0·46 | 0·93 | 1216 |
| 1217 | Vetches | 860 | 13·6 | 264 | 300 | 20 | 69 | 574 | 37 | 19·1 | 0·71 | 85 | 0·88 | 0·88 | 0·65 | 0·92 | 1217 |
| | **12c Oil seeds** | | | | | | | | | | | | | | | | |
| 1218 | Beech mast | 900 | 15·2 | 121 | 149 | 308 | 208 | 288 | 48 | 25·0 | 0·61 | 66 | 0·81 | 0·88 | 0·40 | 0·66 | 1218 |
| 1219 | Cottonseed, Egyptian | 900 | 14·1 | 147 | 216 | 261 | 233 | 236 | 54 | 24·1 | 0·59 | 67 | 0·68 | 0·87 | 0·76 | 0·50 | 1219 |
| 1220 | Cottonseed, Bombay | 900 | 13·1 | 135 | 196 | 212 | 219 | 327 | 47 | 23·0 | 0·57 | 65 | 0·69 | 0·87 | 0·76 | 0·50 | 1220 |
| 1221 | Cottonseed, Brazilian | 900 | 14·1 | 159 | 233 | 256 | 188 | 276 | 48 | 24·2 | 0·58 | 66 | 0·68 | 0·88 | 0·76 | 0·50 | 1221 |
| 1222 | Groundnuts or peanuts | 900 | 21·1 | 256 | 284 | 478 | 28 | 187 | 23 | 29·7 | 0·71 | 85 | 0·90 | 0·90 | 0·08 | 0·84 | 1222 |
| 1223 | Hemp seed | 900 | 17·5 | 150 | 200 | 359 | 164 | 231 | 46 | 26·4 | 0·66 | 76 | 0·75 | 0·90 | 0·60 | 0·80 | 1223 |
| 1224 | Linseed | 900 | 19·3 | 208 | 260 | 392 | 59 | 248 | 41 | 27·4 | 0·71 | 80 | 0·80 | 0·95 | 0·33 | 0·80 | 1224 |
| 1225 | Palm nut kernels | 900 | 23·0 | 87 | 92 | 532 | 63 | 292 | 20 | 30·1 | 0·76 | 88 | 0·94 | 0·95 | 0·60 | 0·84 | 1225 |
| 1226 | Rape seed | 900 | 21·0 | 172 | 212 | 484 | 63 | 194 | 46 | 29·2 | 0·72 | 80 | 0·81 | 0·95 | 0·25 | 0·80 | 1226 |
| 1227 | Sesame seed | 900 | 20·8 | 195 | 217 | 499 | 67 | 159 | 59 | 29·3 | 0·71 | 77 | 0·90 | 0·95 | 0·22 | 0·56 | 1227 |
| 1228 | Soya bean | 900 | 14·9 | 328 | 369 | 194 | 46 | 339 | 52 | 23·1 | 0·64 | 75 | 0·89 | 0·90 | 0·42 | 0·68 | 1228 |
| 1229 | Sunflower seed | 900 | 16·6 | 138 | 153 | 350 | 303 | 157 | 37 | 26·3 | 0·63 | 68 | 0·90 | 0·95 | 0·34 | 0·71 | 1229 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg | | | | | Gross Energy MJ/kg DM | Q {ME/GE} | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal) | | | | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | |
| | **12d Miscellaneous seeds** | | | | | | | | | | | | | | | | |
| 1230 | Acorns, fresh | 500 | 13·6 | 54 | 66 | 48 | 136 | 726 | 24 | 18·9 | 0·72 | 83 | 0·82 | 0·79 | 0·60 | 0·90 | 1230 |
| 1231 | Acorns, dried | 860 | 13·6 | 55 | 67 | 49 | 136 | 724 | 23 | 18·9 | 0·72 | 83 | 0·81 | 0·80 | 0·60 | 0·90 | 1231 |
| 1232 | Buckwheat | 860 | 10·6 | 99 | 131 | 30 | 167 | 638 | 33 | 18·7 | 0·57 | 65 | 0·75 | 0·73 | 0·24 | 0·77 | 1232 |
| 1233 | Corozo nut (vegetable ivory) | 900 | 13·6 | 21 | 51 | 10 | 77 | 850 | 12 | 18·1 | 0·75 | 86 | 0·41 | 0·33 | 0·65 | 0·93 | 1233 |
| 1234 | Horse chestnut, fresh | 500 | 12·1 | 50 | 84 | 30 | 50 | 804 | 32 | 18·3 | 0·66 | 74 | 0·60 | 0·80 | 0·32 | 0·81 | 1234 |
| 1235 | Horse chestnut, dry | 860 | 11·2 | 50 | 85 | 29 | 51 | 803 | 31 | 18·3 | 0·61 | 68 | 0·59 | 0·83 | 0·29 | 0·74 | 1235 |
| 1236 | Locust beans (pods plus seeds) | 860 | 13·8 | 47 | 69 | 15 | 76 | 812 | 29 | 18·0 | 0·77 | 87 | 0·69 | 0·54 | 0·58 | 0·95 | 1236 |
| 1237 | Lucerne seed meal | 880 | 14·1 | 316 | 376 | 119 | 92 | 363 | 50 | 21·5 | 0·65 | 79 | 0·84 | 0·86 | 0·62 | 0·87 | 1237 |
| 1238 | Mangel seed | 880 | 7·5 | 83 | 139 | 61 | 386 | 334 | 80 | 19·0 | 0·40 | 46 | 0·60 | 0·60 | 0·35 | 0·62 | 1238 |
| 1239 | Red clover seed meal | 880 | 13·4 | 313 | 373 | 89 | 106 | 357 | 76 | 20·4 | 0·66 | 78 | 0·84 | 0·87 | 0·82 | 0·86 | 1239 |
| 1240 | Rye grass seed meal (perennial and Italian) | 880 | 11·5 | 72 | 108 | 22 | 105 | 719 | 47 | 18·1 | 0·64 | 71 | 0·67 | 0·84 | 0·21 | 0·83 | 1240 |
| 1241 | Sainfoin seed meal (unmilled seed) | 880 | 11·6 | 258 | 300 | 68 | 203 | 383 | 45 | 20·2 | 0·57 | 69 | 0·86 | 0·88 | 0·41 | 0·75 | 1241 |
| 1242 | Sugar beet seed | 880 | 7·1 | 82 | 136 | 61 | 451 | 277 | 74 | 19·1 | 0·37 | 44 | 0·60 | 0·60 | 0·34 | 0·60 | 1242 |
| | **13 Oil cakes and meals** | | | | | | | | | | | | | | | | |
| 1301 | Beech mast cake, shelled | 900 | 12·6 | 357 | 406 | 94 | 76 | 337 | 88 | 20·4 | 0·62 | 72 | 0·88 | 0·90 | 0·24 | 0·76 | 1301 |
| 1302 | Beech mast cake, unshelled | 900 | 8·9 | 162 | 217 | 101 | 299 | 328 | 56 | 20·6 | 0·43 | 47 | 0·75 | 0·91 | 0·16 | 0·51 | 1302 |
| 1303 | Castor bean meal (de-toxicated) | 900 | 6·2 | 263 | 324 | 16 | 412 | 177 | 71 | 19·0 | 0·32 | 39 | 0·81 | 0·93 | 0·09 | 0·43 | 1303 |
| 1304 | Coconut cake | 900 | 13·0 | 184 | 236 | 81 | 127 | 491 | 66 | 19·7 | 0·66 | 75 | 0·78 | 0·97 | 0·63 | 0·83 | 1304 |
| 1305 | Coconut cake meal | 900 | 12·7 | 174 | 220 | 76 | 153 | 479 | 72 | 19·5 | 0·65 | 74 | 0·79 | 0·97 | 0·63 | 0·83 | 1305 |
| 1306 | Cotton cake, Bombay | 900 | 8·5 | 178 | 231 | 54 | 248 | 401 | 66 | 19·3 | 0·44 | 50 | 0·77 | 0·94 | 0·20 | 0·54 | 1306 |
| 1307 | Cotton cake, Brazilian | 900 | 8·9 | 234 | 304 | 61 | 280 | 304 | 50 | 20·1 | 0·44 | 51 | 0·77 | 0·93 | 0·21 | 0·54 | 1307 |
| 1308 | Cotton cake, Egyptian | 900 | 8·7 | 203 | 263 | 57 | 242 | 372 | 66 | 19·5 | 0·45 | 51 | 0·77 | 0·92 | 0·21 | 0·54 | 1308 |
| 1309 | Cotton cake, decorticated | 900 | 12·3 | 393 | 457 | 89 | 87 | 293 | 74 | 20·8 | 0·59 | 70 | 0·86 | 0·94 | 0·28 | 0·67 | 1309 |
| 1310 | Cotton cake, semi-decorticated | 900 | 11·4 | 366 | 426 | 69 | 143 | 297 | 66 | 20·4 | 0·56 | 66 | 0·86 | 0·93 | 0·27 | 0·66 | 1310 |
| 1311 | Ground nut cake, decorticated | 900 | 12·9 | 449 | 504 | 67 | 72 | 293 | 63 | 20·7 | 0·62 | 76 | 0·89 | 0·90 | 0·08 | 0·85 | 1311 |
| 1312 | Ground nut cake, undecorticated | 900 | 11·4 | 310 | 337 | 101 | 256 | 243 | 63 | 20·9 | 0·55 | 63 | 0·92 | 0·90 | 0·11 | 0·84 | 1312 |
| 1313 | Ground nut meal, decorticated extracted | 900 | 11·7 | 491 | 552 | 8 | 88 | 289 | 63 | 19·6 | 0·60 | 75 | 0·89 | 0·86 | 0·08 | 0·85 | 1313 |
| 1314 | Ground nut meal, undecorticated extracted | 900 | 9·2 | 316 | 343 | 21 | 273 | 316 | 47 | 19·5 | 0·47 | 58 | 0·92 | 0·79 | 0·11 | 0·69 | 1314 |
| 1315 | Hemp seed cake | 900 | 9·0 | 255 | 344 | 97 | 268 | 204 | 87 | 20·5 | 0·44 | 48 | 0·74 | 0·90 | 0·08 | 0·58 | 1315 |
| 1316 | Hemp seed meal | 900 | 6·9 | 296 | 394 | 19 | 291 | 190 | 106 | 18·6 | 0·37 | 43 | 0·75 | 0·77 | 0·08 | 0·53 | 1316 |
| 1317 | Kapok cake | 900 | 8·7 | 232 | 313 | 81 | 299 | 233 | 73 | 20·3 | 0·43 | 48 | 0·74 | 0·91 | 0·20 | 0·50 | 1317 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg | | | | | Gross Energy MJ/kg DM | Q $\left\{\frac{ME}{GE}\right\}$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal) | | | | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | | | | Crude Protein | Ether Extract | Crude Fibre | N free Extract | |
| 1318 | Linseed cake, English made | 900 | 13·4 | 286 | 332 | 107 | 102 | 400 | 59 | 20·9 | 0·64 | 75 | 0·86 | 0·92 | 0·49 | 0·80 | 1318 |
| 1319 | Linseed cake, foreign | 900 | 12·9 | 305 | 354 | 77 | 104 | 402 | 62 | 20·3 | 0·63 | 75 | 0·86 | 0·93 | 0·50 | 0·80 | 1319 |
| 1320 | Linseed meal, extracted | 900 | 11·9 | 348 | 404 | 36 | 102 | 384 | 73 | 19·4 | 0·62 | 74 | 0·86 | 0·90 | 0·50 | 0·80 | 1320 |
| 1321 | Media cake | 900 | 9·6 | 250 | 358 | 117 | 233 | 207 | 86 | 21·0 | 0·46 | 51 | 0·70 | 0·80 | 0·20 | 0·60 | 1321 |
| 1322 | Niger cake | 900 | 10·5 | 292 | 364 | 66 | 203 | 262 | 104 | 19·4 | 0·54 | 62 | 0·80 | 0·81 | 0·27 | 0·84 | 1322 |
| 1323 | Olive cake | 900 | 12·7 | 69 | 71 | 201 | 338 | 329 | 61 | 22·1 | 0·57 | 60 | 0·97 | 0·95 | 0·33 | 0·70 | 1323 |
| 1324 | Palm kernel cake | 900 | 12·8 | 196 | 216 | 68 | 150 | 522 | 44 | 19·8 | 0·65 | 76 | 0·91 | 0·88 | 0·38 | 0·85 | 1324 |
| 1325 | Palm kernel meal, extracted | 900 | 12·2 | 204 | 227 | 10 | 167 | 552 | 44 | 18·5 | 0·66 | 78 | 0·90 | 0·89 | 0·50 | 0·88 | 1325 |
| 1326 | Poppy seed cake | 900 | 11·3 | 322 | 408 | 108 | 92 | 240 | 152 | 19·6 | 0·58 | 62 | 0·79 | 0·93 | 0·49 | 0·64 | 1326 |
| 1327 | Rape cake | 900 | 11·4 | 322 | 388 | 106 | 91 | 280 | 136 | 19·8 | 0·58 | 64 | 0·83 | 0·79 | 0·08 | 0·80 | 1327 |
| 1328 | Rape meal, extracted | 900 | 10·9 | 343 | 413 | 34 | 104 | 366 | 82 | 19·2 | 0·57 | 67 | 0·83 | 0·77 | 0·11 | 0·80 | 1328 |
| 1329 | Sesame cake, English | 900 | 13·0 | 442 | 491 | 131 | 49 | 231 | 98 | 21·5 | 0·61 | 70 | 0·90 | 0·90 | 0·31 | 0·56 | 1329 |
| 1330 | Sesame cake, French | 900 | 11·7 | 371 | 412 | 121 | 187 | 183 | 97 | 21·1 | 0·56 | 64 | 0·90 | 0·90 | 0·31 | 0·56 | 1330 |
| 1331 | Sesame meal, extracted | 900 | 10·4 | 444 | 493 | 26 | 82 | 284 | 114 | 18·8 | 0·55 | 65 | 0·90 | 0·92 | 0·31 | 0·56 | 1331 |
| 1332 | Soya bean cake | 900 | 13·3 | 454 | 504 | 66 | 60 | 308 | 62 | 20·7 | 0·64 | 79 | 0·90 | 0·91 | 0·72 | 0·77 | 1332 |
| 1333 | Soya bean meal, extracted | 900 | 12·3 | 453 | 503 | 17 | 58 | 360 | 62 | 19·5 | 0·63 | 79 | 0·90 | 0·93 | 0·71 | 0·77 | 1333 |
| 1334 | Sunflower cake, decorticated | 900 | 13·3 | 372 | 413 | 152 | 134 | 226 | 74 | 22·1 | 0·60 | 71 | 0·90 | 0·88 | 0·30 | 0·71 | 1334 |
| 1335 | Sunflower cake, undecorticated | 900 | 9·5 | 185 | 206 | 80 | 323 | 311 | 80 | 19·6 | 0·48 | 53 | 0·90 | 0·88 | 0·18 | 0·71 | 1335 |
| 1336 | Sunflower meal, extracted | 900 | 10·4 | 381 | 423 | 11 | 181 | 312 | 72 | 19·0 | 0·54 | 67 | 0·90 | 0·90 | 0·30 | 0·71 | 1336 |
| 1337 | Walnut cake | 900 | 14·7 | 364 | 404 | 141 | 77 | 319 | 59 | 22·0 | 0·67 | 79 | 0·90 | 0·95 | 0·25 | 0·85 | 1337 |
| | **14 Feedingstuffs of animal orgin** | | | | | | | | | | | | | | | | |
| 1401 | Blood meal | 900 | 13·2 | 848 | 942 | 9 | 0 | 18 | 31 | 22·0 | 0·60 | 86 | 0·90 | 1·00 | 0·00 | 0·00 | 1401 |
| 1402 | Fish meal, white | 900 | 11·1 | 631 | 701 | 40 | 0 | 18 | 241 | 17·8 | 0·62 | 68 | 0·90 | 0·94 | 0·00 | 0·80 | 1402 |
| 1403 | Greaves | 900 | 18·2 | 615 | 648 | 281 | 0 | 0 | 71 | 26·1 | 0·70 | 87 | 0·95 | 0·92 | 0·00 | 0·00 | 1403 |
| 1404 | Pure meat meal | 900 | 16·3 | 753 | 810 | 148 | 0 | 0 | 42 | 24·3 | 0·67 | 89 | 0·93 | 0·95 | 0·00 | 0·00 | 1404 |
| 1405 | Feeding meat meal (High fat) | 900 | 13·3 | 624 | 663 | 121 | 0 | 6 | 210 | 20·0 | 0·66 | 74 | 0·94 | 0·89 | 0·00 | 1·00 | 1405 |
| 1406 | Feeding meat meal (Low fat) | 900 | 11·1 | 631 | 717 | 31 | 0 | 43 | 209 | 18·2 | 0·61 | 70 | 0·88 | 0·83 | 0·00 | 0·98 | 1406 |
| 1407 | Meat and Bone meal (High protein) | 900 | 9·7 | 465 | 597 | 50 | 0 | 62 | 291 | 16·6 | 0·58 | 57 | 0·78 | 0·95 | 0·00 | 0·98 | 1407 |
| 1408 | Meat and Bone meal (Medium (protein) | 900 | 7·9 | 411 | 527 | 44 | 0 | 17 | 412 | 14·0 | 0·57 | 47 | 0·78 | 0·95 | 0·00 | 0·98 | 1408 |
| 1409 | Milk, cows whole | 128 | 20·2 | 250 | 266 | 305 | 0 | 375 | 55 | 25·0 | 0·81 | 93 | 0·94 | 1·00 | 0·00 | 1·00 | 1409 |
| 1410 | Milk, buttermilk | 92 | 15·7 | 368 | 391 | 87 | 0 | 446 | 76 | 20·3 | 0·77 | 90 | 0·94 | 1·00 | 0·00 | 1·00 | 1410 |
| 1411 | Milk, separated | 94 | 14·1 | 350 | 372 | 11 | 0 | 532 | 85 | 18·3 | 0·77 | 89 | 0·94 | 1·00 | 0·00 | 1·00 | 1411 |
| 1412 | Milk, skimmed, deep set | 97 | 14·8 | 339 | 361 | 41 | 0 | 515 | 82 | 19·0 | 0·78 | 90 | 0·94 | 1·00 | 0·00 | 1·00 | 1412 |
| 1413 | Milk, skimmed, shallow set | 100 | 15·3 | 329 | 350 | 70 | 0 | 500 | 80 | 19·6 | 0·78 | 90 | 0·94 | 1·00 | 0·00 | 1·00 | 1413 |
| 1414 | Milk, whey | 66 | 14·5 | 91 | 106 | 30 | 0 | 758 | 106 | 17·0 | 0·85 | 88 | 0·86 | 1·00 | 0·00 | 1·00 | 1414 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q $\left(\frac{ME}{GE}\right)$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **15 By-products** | | | | | | | | | | | | | | | | |
| 1501 | Apple pomace, fresh | 250 | 8·4 | 28 | 60 | 44 | 184 | 656 | 56 | 18·3 | 0·46 | 51 | 0·47 | 0·45 | 0·00 | 0·70 | 1501 |
| 1502 | Apple pomace, dried | 900 | 7·7 | 18 | 46 | 40 | 308 | 587 | 20 | 19·0 | 0·41 | 47 | 0·40 | 0·49 | 0·06 | 0·70 | 1502 |
| 1503 | Fine barley dust | 860 | 13·5 | 101 | 136 | 26 | 52 | 750 | 36 | 18·4 | 0·73 | 83 | 0·74 | 0·91 | 0·24 | 0·92 | 1503 |
| 1504 | Barley, brewers' grains, fresh | 220 | 10·0 | 149 | 205 | 64 | 186 | 500 | 45 | 19·6 | 0·51 | 59 | 0·73 | 0·86 | 0·39 | 0·62 | 1504 |
| 1505 | Barley, brewers' grains, ensiled | 280 | 10·0 | 149 | 204 | 64 | 189 | 500 | 43 | 19·7 | 0·51 | 59 | 0·73 | 0·86 | 0·39 | 0·62 | 1505 |
| 1506 | Barley, brewers' grains, dried | 900 | 10·3 | 145 | 204 | 71 | 169 | 512 | 43 | 19·8 | 0·52 | 60 | 0·71 | 0·88 | 0·48 | 0·60 | 1506 |
| 1507 | Barley, distillers' grains, fresh | 250 | 11·8 | 237 | 320 | 116 | 136 | 396 | 32 | 21·6 | 0·55 | 65 | 0·74 | 0·87 | 0·47 | 0·62 | 1507 |
| 1508 | Barley, distillers' grains, dried | 900 | 12·1 | 214 | 301 | 126 | 110 | 443 | 20 | 21·9 | 0·55 | 65 | 0·71 | 0·88 | 0·48 | 0·62 | 1508 |
| 1509 | Barley, ale and porter grains, fresh | 250 | 10·2 | 178 | 240 | 76 | 212 | 428 | 44 | 20·2 | 0·51 | 59 | 0·74 | 0·86 | 0·39 | 0·62 | 1509 |
| 1510 | Barley ale and porter grains, dried | 900 | 10·3 | 153 | 219 | 74 | 194 | 477 | 36 | 20·1 | 0·51 | 60 | 0·70 | 0·88 | 0·48 | 0·60 | 1510 |
| 1511 | Barley malt culms | 900 | 11·2 | 222 | 271 | 22 | 156 | 471 | 80 | 18·4 | 0·61 | 72 | 0·82 | 0·75 | 0·91 | 0·73 | 1511 |
| 1512 | Bean husks (chaff or hulls) | 900 | 9·4 | 0 | 40 | 2 | 488 | 421 | 49 | 17·8 | 0·53 | 67 | 0·00 | 1·00 | 0·88 | 0·57 | 1512 |
| 1513 | Broad bean pod meal | 900 | 10·4 | 112 | 167 | 11 | 178 | 571 | 73 | 17·7 | 0·59 | 67 | 0·67 | 0·60 | 0·58 | 0·79 | 1513 |
| 1514 | Fodder-cellulose (from wheat straw by paper process) | 900 | 10·3 | 0 | 3 | 6 | 798 | 162 | 31 | 18·5 | 0·56 | 79 | 0·00 | 0·00 | 0·91 | 0·38 | 1514 |
| 1515 | Flax chaff (containing about 10 per cent seed) | 860 | 6·5 | 55 | 92 | 57 | 369 | 402 | 80 | 18·6 | 0·35 | 40 | 0·60 | 0·74 | 0·46 | 0·32 | 1515 |
| 1516 | Hominy chop, high grade | 900 | 14·7 | 78 | 118 | 89 | 49 | 716 | 29 | 19·9 | 0·74 | 84 | 0·66 | 0·91 | 0·75 | 0·90 | 1516 |
| 1517 | Hominy chop, low grade | 900 | 14·1 | 70 | 106 | 69 | 94 | 701 | 30 | 19·4 | 0·73 | 83 | 0·66 | 0·90 | 0·75 | 0·90 | 1517 |
| 1518 | Hops, spent, fresh | 250 | 6·3 | 52 | 172 | 76 | 236 | 456 | 60 | 19·6 | 0·32 | 35 | 0·30 | 0·63 | 0·17 | 0·47 | 1518 |
| 1519 | Hops, spent, dried | 900 | 6·4 | 53 | 172 | 77 | 236 | 443 | 72 | 19·4 | 0·33 | 36 | 0·31 | 0·65 | 0·17 | 0·48 | 1519 |
| 1520 | Horse-chestnut meal (alcohol-extracted) | 900 | 10·1 | 0 | 73 | 74 | 80 | 746 | 27 | 19·4 | 0·52 | 58 | 0·00 | 0·60 | 0·00 | 0·72 | 1520 |
| 1521 | Horse-chestnut meal (water extracted) | 900 | 9·9 | 0 | 78 | 78 | 84 | 736 | 24 | 19·6 | 0·51 | 57 | 0·00 | 0·66 | 0·00 | 0·70 | 1521 |
| 1522 | Lentil husks (chaff or hulls) | 900 | 9·0 | 15 | 127 | 8 | 291 | 539 | 36 | 18·3 | 0·49 | 60 | 0·12 | 1·00 | 0·67 | 0·70 | 1522 |
| 1523 | Maize, flaked | 900 | 15·0 | 106 | 110 | 49 | 17 | 814 | 10 | 19·2 | 0·78 | 92 | 0·96 | 0·47 | 0·33 | 0·97 | 1523 |
| 1524 | Maize germ meal, high fat | 900 | 14·9 | 116 | 146 | 140 | 46 | 628 | 41 | 21·0 | 0·71 | 80 | 0·80 | 0·92 | 0·61 | 0·84 | 1524 |
| 1525 | Maize germ meal, low fat | 900 | 13·2 | 90 | 112 | 36 | 34 | 779 | 39 | 18·4 | 0·71 | 80 | 0·80 | 0·92 | 0·61 | 0·84 | 1525 |
| 1526 | Maize meal, degermed, cooked | 900 | 15·6 | 99 | 104 | 17 | 14 | 856 | 9 | 18·5 | 0·85 | 97 | 0·95 | 0·87 | 0·92 | 0·99 | 1526 |
| 1527 | Maize bran | 900 | 12·5 | 62 | 96 | 47 | 132 | 704 | 21 | 19·1 | 0·66 | 75 | 0·65 | 0·86 | 0·33 | 0·86 | 1527 |
| 1528 | Maize, gluten feed | 900 | 13·5 | 223 | 262 | 38 | 39 | 633 | 28 | 19·4 | 0·70 | 83 | 0·85 | 0·79 | 0·71 | 0·87 | 1528 |
| 1529 | Maize, gluten meal | 900 | 14·2 | 339 | 394 | 52 | 23 | 518 | 12 | 20·7 | 0·69 | 85 | 0·86 | 0·94 | 0·00 | 0·90 | 1529 |
| 1530 | Maize, malt culms | 860 | 15·1 | 201 | 240 | 167 | 67 | 457 | 69 | 21·6 | 0·70 | 80 | 0·84 | 0·86 | 0·78 | 0·88 | 1530 |
| 1531 | Maize, feeding meal from corn flour | 900 | 13·8 | 188 | 227 | 49 | 56 | 658 | 11 | 19·8 | 0·69 | 84 | 0·83 | 0·80 | 0·66 | 0·87 | 1531 |

| Food Number | Food Name | Dry Matter Content g/kg | Metabolisable Energy MJ/kg DM | Digestible Crude Protein g/kg DM | Analysis of Dry Matter g/kg: Crude Protein | Ether Extract | Crude Fibre | N free Extract | Total Ash | Gross Energy MJ/kg DM | Q $\left\{\frac{ME}{GE}\right\}$ | Digestible Organic Matter in Dry Matter DOMD% | Digestibility Coefficients (decimal): Crude Protein | Ether Extract | Crude Fibre | N free Extract | Food Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1532 | Maize, starch feed | 900 | 14·1 | 211 | 251 | 76 | 83 | 580 | 10 | 20·6 | 0·69 | 83 | 0·84 | 0·90 | 0·72 | 0·85 | 1532 |
| 1533 | Malt, dry | 900 | 12·9 | 118 | 148 | 33 | 97 | 694 | 28 | 18·8 | 0·68 | 80 | 0·80 | 0·77 | 0·50 | 0·87 | 1533 |
| 1534 | Oat bran } from preparation | 900 | 8·8 | 44 | 89 | 40 | 242 | 562 | 67 | 18·2 | 0·49 | 55 | 0·50 | 0·56 | 0·37 | 0·70 | 1534 |
| 1535 | Oat-meal } of oat-meal | 900 | 12·4 | 131 | 174 | 73 | 18 | 712 | 22 | 19·9 | 0·62 | 72 | 0·75 | 0·81 | 0·50 | 0·73 | 1535 |
| 1536 | Oat husks | 900 | 4·9 | 0 | 21 | 11 | 351 | 574 | 42 | 17·8 | 0·28 | 33 | 0·00 | 0·40 | 0·33 | 0·36 | 1536 |
| 1537 | Pea husks (chaff or hulls) | 860 | 12·5 | 41 | 60 | 8 | 545 | 355 | 31 | 18·4 | 0·68 | 88 | 0·68 | 0·71 | 0·94 | 0·90 | 1537 |
| 1538 | Pea pod meal (from canning industry) | 900 | 10·7 | 108 | 150 | 13 | 169 | 604 | 63 | 17·9 | 0·60 | 69 | 0·72 | 0·67 | 0·63 | 0·77 | 1538 |
| 1539 | Potato sludge | 860 | 9·9 | 0 | 40 | 1 | 102 | 793 | 64 | 16·9 | 0·58 | 62 | 0·00 | 0·00 | 0·13 | 0·77 | 1539 |
| 1540 | Potato slump | 900 | 6·6 | 135 | 270 | 41 | 106 | 453 | 130 | 17·8 | 0·37 | 40 | 0·50 | 0·49 | 0·21 | 0·50 | 1540 |
| 1541 | Potato pulp (dry) | 860 | 10·8 | 0 | 40 | 1 | 102 | 793 | 64 | 16·9 | 0·64 | 68 | 0·00 | 0·00 | 0·24 | 0·83 | 1541 |
| 1542 | Potato cossettes (meal) | 900 | 12·4 | 54 | 98 | 6 | 22 | 834 | 40 | 17·6 | 0·70 | 78 | 0·55 | 0·00 | 0·50 | 0·86 | 1542 |
| 1543 | Potato flakes | 900 | 13·3 | 42 | 91 | 3 | 23 | 840 | 42 | 17·5 | 0·76 | 84 | 0·46 | 0·00 | 0·48 | 0·94 | 1543 |
| 1544 | Potato slices | 900 | 13·1 | 45 | 104 | 2 | 18 | 832 | 43 | 17·5 | 0·75 | 83 | 0·43 | 0·00 | 0·50 | 0·93 | 1544 |
| 1545 | Rice meal | 900 | 12·7 | 82 | 141 | 150 | 70 | 544 | 94 | 20·3 | 0·62 | 66 | 0·58 | 0·85 | 0·25 | 0·79 | 1545 |
| 1546 | Rice sludge, dried | 860 | 13·6 | 250 | 305 | 24 | 13 | 642 | 16 | 19·5 | 0·70 | 85 | 0·82 | 0·48 | 0·64 | 0·91 | 1546 |
| 1547 | Rye bran | 880 | 11·2 | 143 | 191 | 35 | 59 | 664 | 51 | 18·6 | 0·60 | 68 | 0·75 | 0·77 | 0·33 | 0·74 | 1547 |
| 1548 | Seaweed meal (dried): Laminaria | 860 | 8·8 | 73 | 136 | 13 | 102 | 548 | 201 | 15·3 | 0·58 | 56 | 0·54 | 0·82 | 0·73 | 0·73 | 1548 |
| 1549 | Seaweed meal (dried): Fucus | 860 | 8·8 | 0 | 58 | 48 | 106 | 605 | 184 | 16·0 | 0·55 | 51 | 0·00 | 0·95 | 0·66 | 0·66 | 1549 |
| 1550 | Sugar beet pulp, pressed | 180 | 12·7 | 66 | 106 | 6 | 206 | 644 | 39 | 18·0 | 0·71 | 84 | 0·63 | 0·00 | 0·90 | 0·91 | 1550 |
| 1551 | Sugar beet pulp, dried | 900 | 12·7 | 59 | 99 | 7 | 203 | 657 | 34 | 18·0 | 0·71 | 84 | 0·60 | 0·00 | 0·89 | 0·91 | 1551 |
| 1552 | Sugar beet pulp, molassed | 900 | 12·2 | 61 | 106 | 6 | 144 | 662 | 82 | 17·1 | 0·71 | 79 | 0·58 | 0·00 | 0·89 | 0·91 | 1552 |
| 1553 | Sugar beet molasses | 750 | 12·9 | 16 | 47 | 0 | 0 | 884 | 69 | 16·7 | 0·77 | 81 | 0·34 | 0·00 | 0·00 | 0·90 | 1553 |
| 1554 | Sugar cane molasses | 750 | 12·7 | 14 | 41 | 0 | 0 | 872 | 87 | 16·4 | 0·78 | 80 | 0·35 | 0·00 | 0·00 | 0·90 | 1554 |
| 1555 | Tapioca flour | 900 | 15·0 | 13 | 20 | 6 | 29 | 922 | 23 | 17·6 | 0·86 | 95 | 0·67 | 0·20 | 0·76 | 0·99 | 1555 |
| 1556 | Wheat feeds, middlings | 880 | 11·9 | 129 | 176 | 41 | 86 | 650 | 47 | 18·8 | 0·63 | 72 | 0·73 | 0·87 | 0·23 | 0·82 | 1556 |
| 1557 | Wheat feeds, bran | 880 | 10·1 | 126 | 170 | 45 | 114 | 603 | 67 | 18·6 | 0·55 | 61 | 0·74 | 0·69 | 0·22 | 0·71 | 1557 |
| 1558 | Yeast, dried | 900 | 11·7 | 381 | 443 | 11 | 2 | 441 | 102 | 18·3 | 0·64 | 75 | 0·86 | 0·40 | 0·00 | 0·82 | 1558 |
| 1559 | Yeast, wood sugar (dried) | 900 | 12·6 | 471 | 523 | 14 | 0 | 381 | 81 | 19·2 | 0·66 | 81 | 0·90 | 0·23 | 0·00 | 0·88 | 1559 |

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